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FUNDAMENTAL BLAST STUDIES

Louis Giglio-Tos

Defense Nuclear Agency
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POR-6744
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MIDDLE NORTH SERIES DIAL PACK EVENT

PROJECT OFFICERS REPORT

PROJECT LN101

FUNDAMENTAL BLAST STUDIES

HEADQUARTERS
DEFENSE NUCLEAR AGENCY
WASHINGTON, D.C. 20305

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Louis Giglio-Tos, Project Officer
U.S. Army Aberdeen Research
and Development Center
Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

Free-field airblast parameters were measured from the detonation of a spherical 500-ton TNT charge. The charge was placed on the ground such that its height of burst would be one radius above the earth's surface. Measured values of shock-wave arrival time, maximum overpressure, positive phase duration, overpressure impulse, dynamic pressure, and dynamic pressure impulse are presented as functions of ground range and are compared with predictions generated from scaled empirical and theoretical data. Results are compared with those from PRAIRIE FLAT.

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CHAPTER 1

INTRODUCTION

The DIAL PACK Event was a 500-ton TNT shock and blast experiment conducted on 23 July 1970 at the Canadian Defence Research Establishment, Suffield (DRES), under the auspices of the Technical Cooperation Program (TTCP), Panel N-2.

Project LN101 was sponsored by the Defense Nuclear Agency (DNA) to participate in the DIAL PACK Event and to serve as the primary source for basic blast documentation. The DIAL PACK Event was the second major field trial in the MIDDLE NORTH Series.

The energy source for this blast and shock experiment was a 500-ton block-built TNT sphere tangent to and above the ground surface. The lower half of the charge was supported by special high-strength styrofoam precut to follow the contour of the charge. The styrofoam and TNT rested on a layer of four sheets of 3/4-inch plywood, as shown in figures 1.1 and 1.2.

1.1. OBJECTIVES.

The objectives of Project LN101 were: (1) to measure the overpressure versus time history of the shock wave as it traversed instrument stations at selected locations along two blast lines, (2) to document basic blast parameters in the vicinity of target response projects, and (3) to document blast parameters at two elevated stations (10 and 25 feet) to check experimentally the Air Force Weapons Laboratory (AFWL) computer output (LN103) at elevated stations as well as surface stations. The information from the elevated stations will also be used as input loading for the trees exposed by Project LN108.

The primary parameters of the blast wave to be measured were time of arrival, peak overpressure, duration, and impulse. A limited number of stations were instrumented to determine dynamic pressure and dynamic-pressure impulse.

An additional objective of Project LN101 was to document the free-field air-blast parameters produced by the blast-directing experiment being conducted as a follow-on shot by Project LN105. The details of this objective and the results are presented as part of Project LN105.

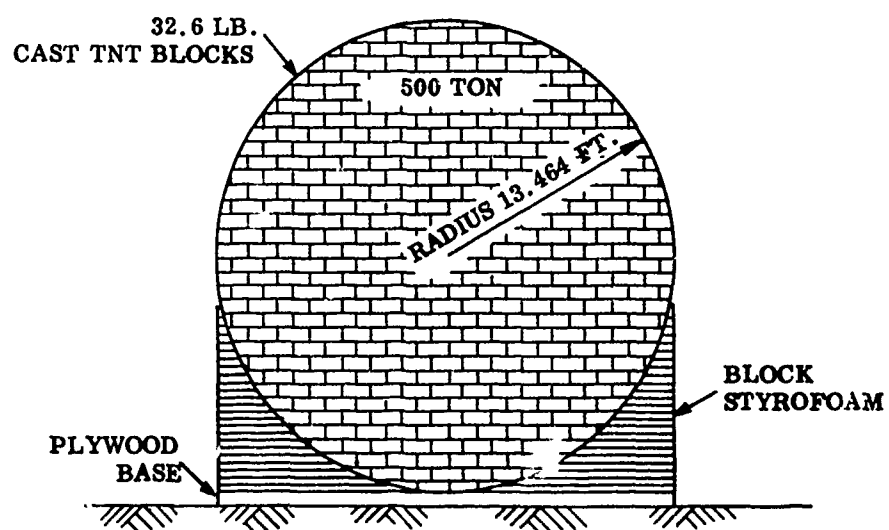


Figure 1.1. --Cross section of charge and support.

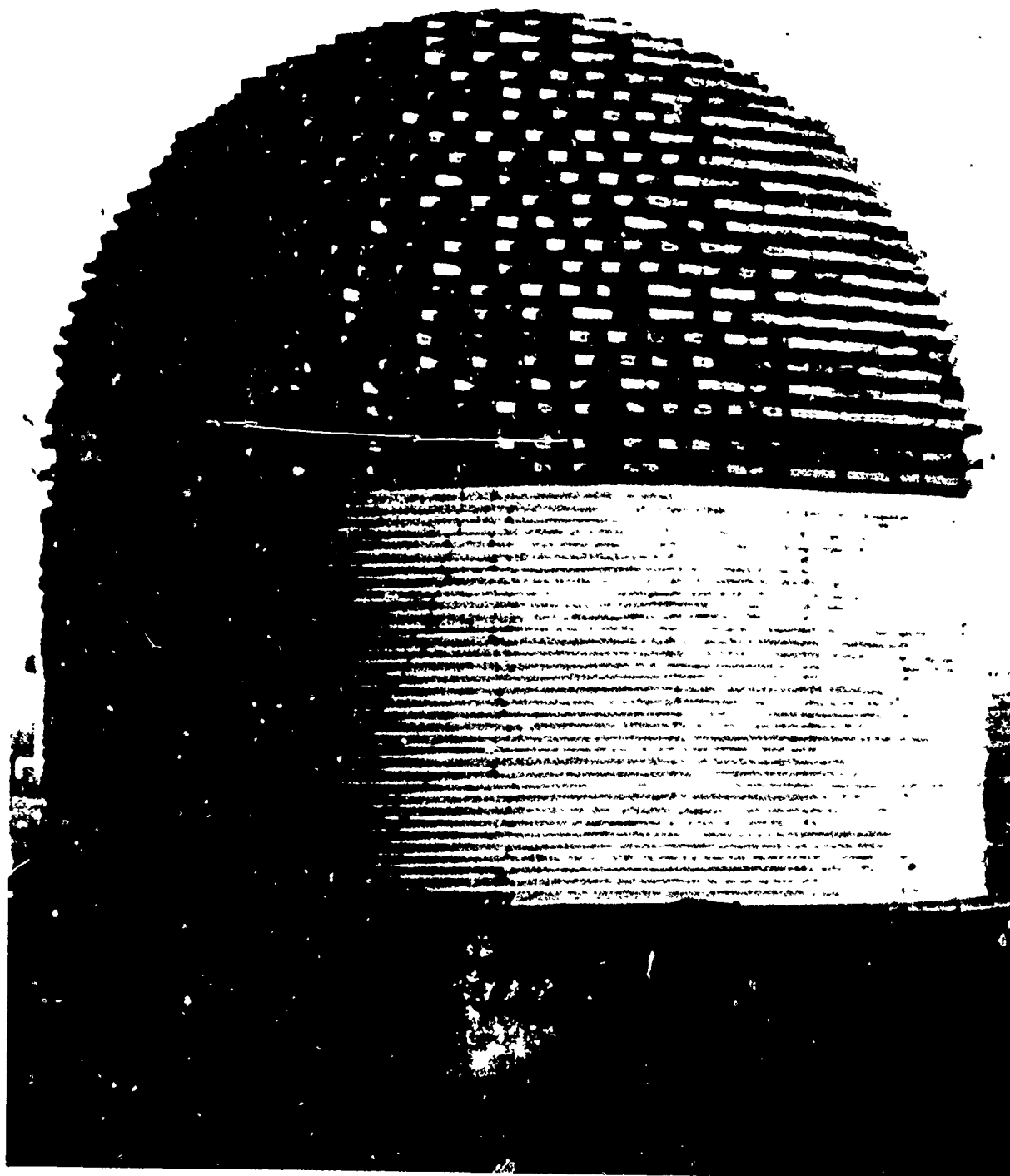


Figure 1.2. DIAL PACK 500-ton char.

1.2. BACKGROUND AND THEORY.

The Ballistic Research Laboratories (BRL) has participated in many phases of research associated with large-scaled, high-explosive detonations as well as nuclear detonations. One of the latest and most pertinent tests was the PRAIRIE FLAT Event (reference 1), which was also a 500-ton TNT sphere resting on the surface.

Because of unpredictable blast anomalies that have been associated with large-scale TNT tests (see Project LN102), the predicted airblast parameters are based on both experimental data and theoretical calculations. The experimental data were based on Events 8a and 6 of Operation DISTANT PLAIN, a 20-ton and 100-ton TNT sphere (reference 2) resting on the surface, and PRAIRIE FLAT Event, a 500-ton TNT sphere. The predictions used from theoretical calculations are based on the AFWL program, which proved to be of great value on the aforementioned operations. This program has been expanded and refined and is described in the Project LN103 report.

CHAPTER 2

PROCEDURE

Three areas of activity will be discussed in this section. These will be the experimental plan and field layout under Experimental Plan, gage types, recorder, calibration techniques under Instrumentation, and the treatment of the recorded data under Data Reduction.

2.1. EXPERIMENTAL PLAN.

The primary blast line was established along an azimuth of 220 degrees. The basic side-on overpressure stations started at 20 feet from GZ where the predicted overpressure was 8,000 psi and extended out to 12,000 feet where the predicted overpressure was 0.2 psi. Blast line number 2 was located along an azimuth of 98 degrees, with fewer stations but with many support measurements for other projects made within a sector. The station locations and type of instrumentation at each are shown in figure 2.1. The gage bearing, ground range, elevation, and measured results are given in tables 3.2 and 3.3.

The basic gage mount showing the installation of a side-on or incident overpressure gage and a total pressure gage is shown in figure 2.2. There were two stations with gages installed at 10- and 25-foot elevations to meet one of the stated objectives. These stations utilized the gun-barrel-type mounts shown in figure 2.3.

2.2 INSTRUMENTATION.

The basic units of the data acquisition systems used were 14-channel magnetic tape recorders (Bell & Howell VR-3300 and VR 3800). Twelve channels are used for wide-band (d. c. to 20 KHz) FM recording of data, and two channels are used for multiplexing a time reference and a time zero signal. Reproduce heads and associated electronics are incorporated in each of the VR-3800 machines. B&F Instruments, Inc. Model 30-100F power supplies and PC2423 signal conditioning equipment were used to supply gage excitation, bridge balancing, and remote shunt calibration. A single-step remote shunt calibration was used to detect system gain changes. Newport Lab Model 60 d. c. amplifiers were used to amplify the transducer signal output to the required level of the FM

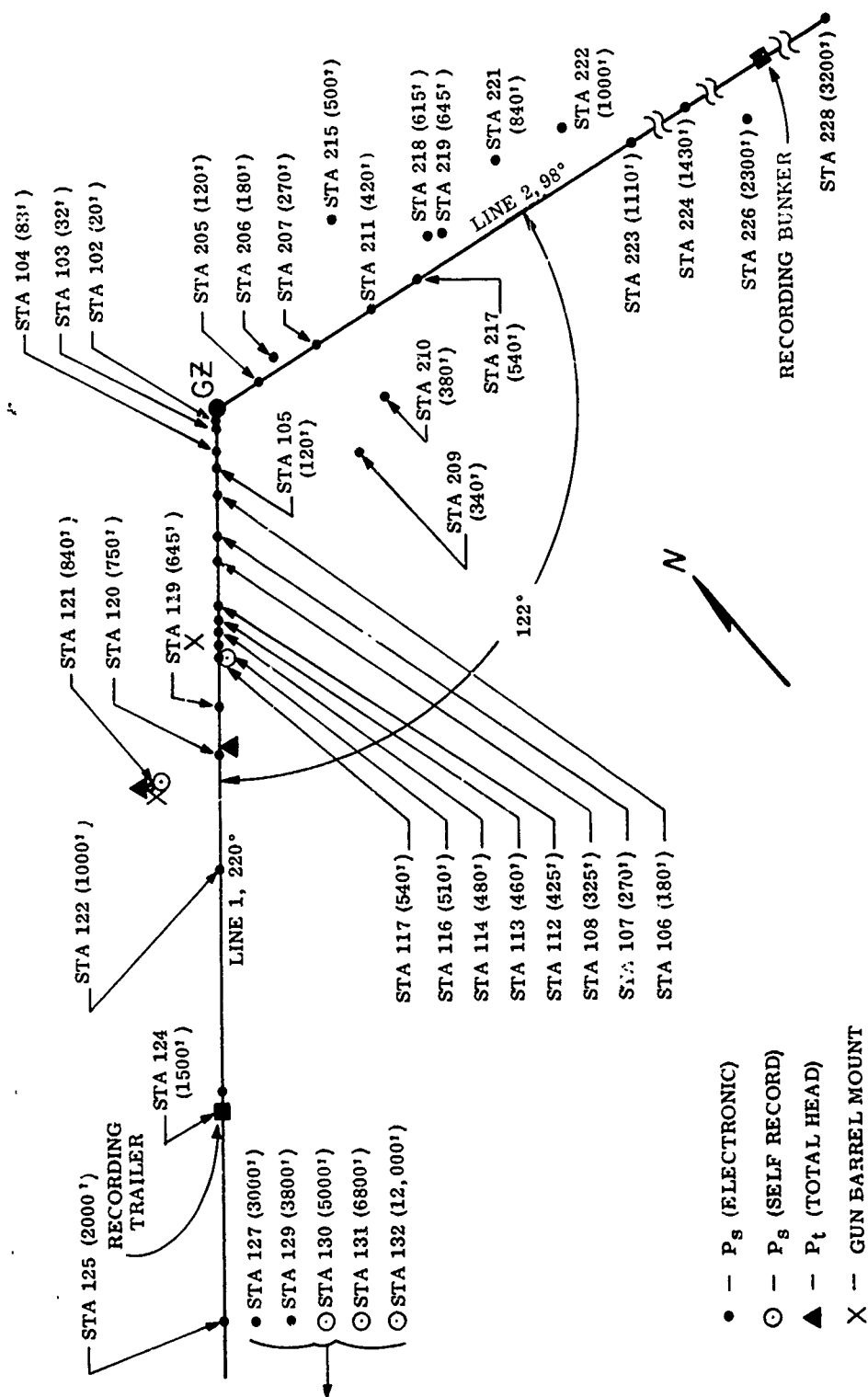


Figure 2.1. ---Field layout



Figure 2.2. -- Typical surface instrumentation station.

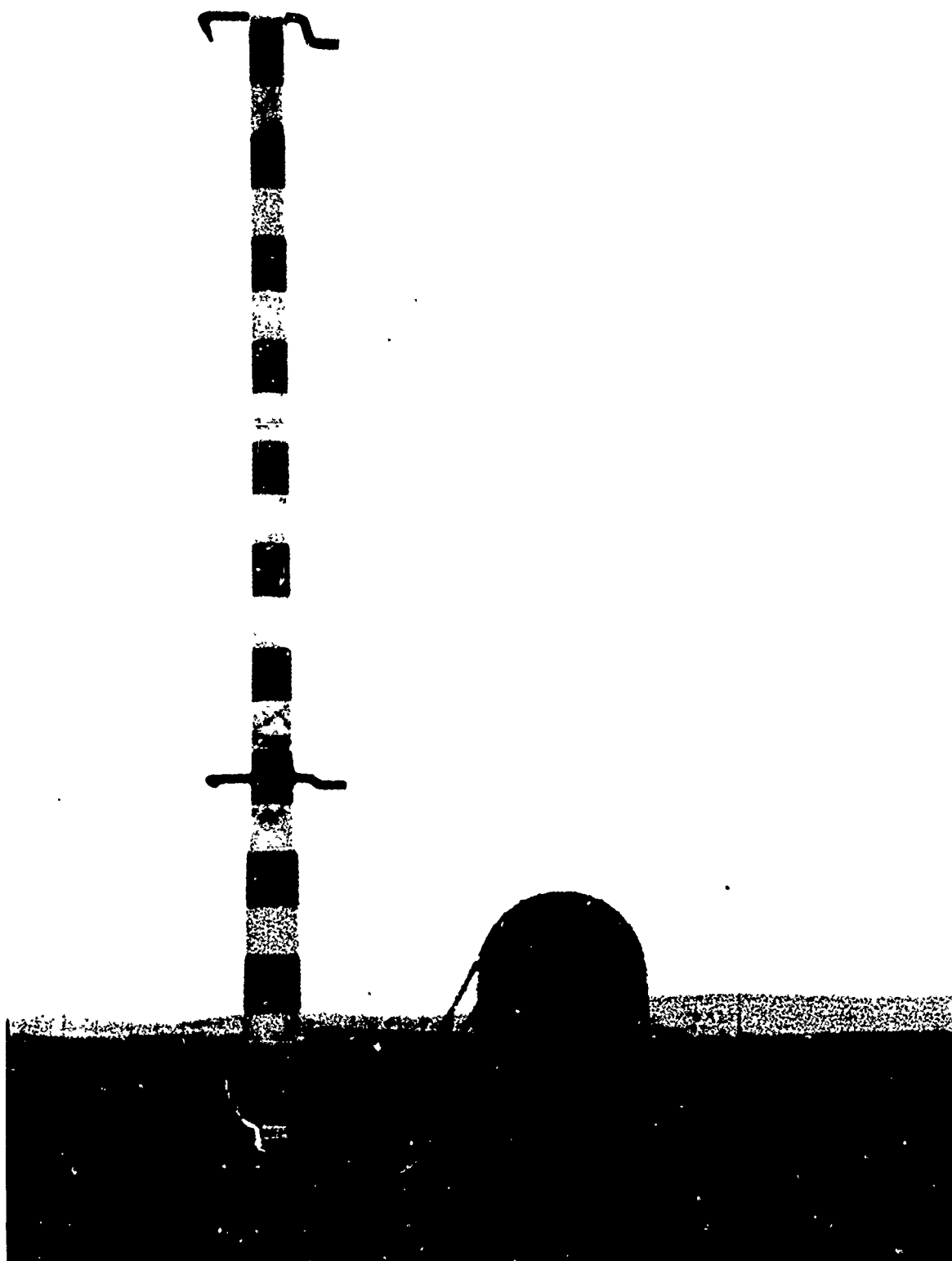


Figure 2.3. --Typical surface and elevated instrumentation station.

record amplifiers. The systems were remotely operated by timing signals furnished by the DRES control bunker.

The Bytrex Model HFG pressure transducer was employed. This transducer has a four-arm Wheatstone bridge with two active semiconductor arms and two dummy arms. The semiconductor strain gages are bonded to a force summing column which is attached to a force collecting diaphragm. The transducer has the basic configuration of a 1-1/8-inch threaded cylinder, 3 inches long, supplied with a shield over the sensitive area of the diaphragm to protect it from thermal radiation and debris damage. The transducers were operated with a constant d.c. voltage excitation of 20 volts and a nominal full-scale output of 100 millivolts. The natural frequency of the transducer varies from 30 KHz to 80 KHz depending on pressure range.

Several mechanical self-recording overpressure-versus-time gages were used. These gages, which were developed at ERL, have a flexible diaphragm as the pressure sensing medium. This diaphragm is basically a convoluted flexure disk welded into an interchangeable mount, with a recording stylus attached. The recording medium is a moving stainless-steel tape, microhoned on one surface, which records the position of the pressure stylus in reference to a fixed stylus trace. A third stylus records a time trace (100 or 500 Hz) supplied by a generator within the gage. The recording tape is driven by a negator spring device at a governed travel rate of about 3 ips. The gage is initiated by means of an externally supplied signal. An arming switch is conveniently located on the top surface of the gage. A detailed description of the gages will be found in references 3 and 4.

The Bytrex transducers were statically calibrated, from forcing function through recorded media, in precisely the configuration used to acquire data during the event. As this is done, the linearity is checked and the shunt-calibration resistance is adjusted to yield 100 percent of the predicted pressure. The shunt calibration is used only as a system gain check between static calibration and actual data acquisition. The linearity check is accomplished by applying 20 percent steps from 0 percent through 120 percent of predicted pressure. Bottled nitrogen is used as the pressure source.

Dynamic testing of the various measurement systems was performed in shock tubes at BRL prior to their use in the field. However, this method of testing is presently limited to peak pressures below 2,000 psi.

2.3. METHOD OF DATA REDUCTION.

The electronic pressure-time history recorded on magnetic tape as analog data was converted to a digital format and stored using the BRL A to D facilities. To eliminate tape-speed errors in the various tape transports, a 100-KHz time reference recorded concurrently with the data acquisition was used as the digitized clock. Electronic and physical forcing function calibrations were also digitized with the actual data.

The Ballistics Research Laboratories Electronic Scientific Computer (BRI-ESC) used these digital tapes to produce the actual computations of pressure and pressure-impulse history. The computer was also employed to obtain dynamic pressure-time, dynamic pressure impulse-time, time-of-arrival, and positive-phase duration data.

The static calibrations recorded prior to the event were used to convert the data to engineering units. The electrical calibration step taken at transducer calibration time and at minus 5 seconds was used to correct the computed values for system gain change.

CHAPTER 3

RESULTS

3.1. ENVIRONMENTAL CONDITIONS. The environmental conditions prevailing at the time of detonation of the DIAL PACK Event are presented in table 3.1.

3.2. INSTRUMENTATION PERFORMANCE.

Data was obtained from 62 of the 70 channels instrumented. The overall quality of the data was satisfactory. The first three stations on line 1 (above 1,500 psi) malfunctioned and did not yield reliable data. Five other channels were lost due to gage and/or cable failure.

Shock-wave perturbations occurred in the pressure-time records above the 20-psi region; below the 20-psi level, the waveforms begin to show the normal classical decay. Typical records may be seen in figures A.3 and A.6 in the appendix. Multiple shocks were experienced at a number of stations on both blast lines.

Presented in figure 3.1 is a photograph of the detonation; in figure 3.2 an aerial view of the explosion is presented. Four luminous precursor jets and two nonluminous surface precursor jets were observed along with three shock-wave perturbations, reference 5. These facts lead to the opinion that the instrumentation systems faithfully recorded the phenomena, and the anomalous waveforms were caused by the jetting just described.

3.3. PRESENTATION OF DATA.

The airblast data for DIAL PACK is listed in tables 3.2 through 3.4; the parameters are plotted versus ground range in figures 3.3 through 3.8. Data obtained in support of other projects was submitted directly to them and will not be reported herein, excepting the free-field measurements.

The data from the elevated sensor positions indicate no significant difference from the ground surface stations in arrival time, maximum overpressure, positive phase duration, and overpressure measurements. These data are plotted with the overpressure data discussed above

TABLE 3.1. -- Environmental Conditions

| | | |
|---------------------|--|--------------------|
| Firing time: | 23 July 1970, at 1100 hours | |
| Charge weight: | 999,123 lbs | |
| Ambient pressure: | 13.57 psi | |
| Temperature | | |
| Surface: | 92.1°F | |
| 1 meter: | 75.5°F | |
| Relative humidity: | 61% | |
| Sun: | Bright, 3/10 cumulus, scattered over whole sky | |
| Surface conditions: | Good | |
| Wind: | 0.5 meter | 3.2 m.p.h. at 140° |
| | 2.0 meters | 1.7 m.p.h. at 125° |
| | 8.0 meters | 4.1 m.p.h. at 145° |



Figure 3.1. --Detonation of DIAL PACK.

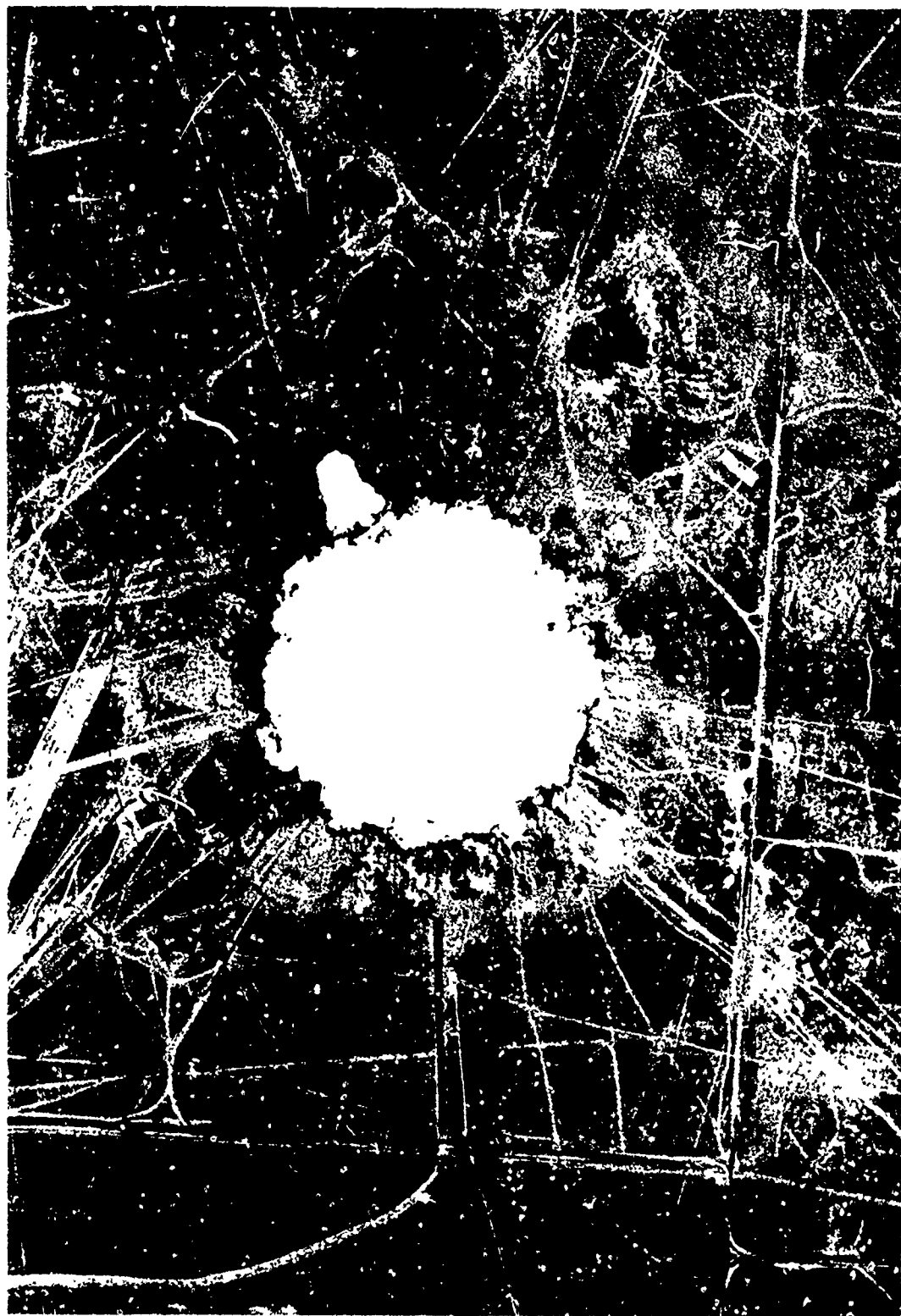


Figure 3.2. --Aerial photograph of burst showing jetting.

TABLE 3.2. --- Results of side-on measurements, line 1

| Station | Ground Range (ft.) | Elevation (ft.) | Recorder (Sys/Ch) | Arrival Time (msec) | Maximum Overpressure (psi) | Positive Duration (msec) | Overpressure Impulse (psi-msec) | Remarks |
|---------|--------------------------|--------------------|----------------------|---------------------------|----------------------------------|--------------------------------|---------------------------------------|--------------|
| 102 | 20 | 0 | 2/1 | 1.51 | --- | --- | --- | Gage failure |
| 102A | 20 | 0 | 1/1 | 1.48 | --- | --- | --- | Gage failure |
| 103 | 32 | 0 | 3/1 | 1.92 | --- | --- | --- | Gage failure |
| 104 | 83 | 0 | 4/1 | 5.61 | 1,260.0 | 25.5 | 2,684.4 | |
| 105 | 120 | 0 | 5/1 | 9.05 | 1,175.0 | 17.5 | 1,580.8 | |
| 106 | 180 | 0 | 1/2 | 8.46 | --- | --- | --- | Gage failure |
| 107 | 270 | 0 | 2/2 | 30.22 | 264.0 | 135.5 | 4,003.0 | |
| 108 | 325 | 0 | 3/2 | 42.65 | 209.0 | 81.7 | 2,618.0 | |
| 112 | 425 | 0 | 4/2 | 71.22 | 88.0 | 134.0 | 1,973.7 | |
| 113 | 460 | 0 | 5/3 | 82.30 | --- | --- | --- | Cable break |
| 114 | 480 | 0 | 1/4 | 89.00 | 70.9 | 108.0 | 1,327.8 | |
| 116 | 510 | 0 | 2/12 | 100.88 | 55.4 | 93.2 | 1,243.8 | |
| 117 | 540 | 0 | 3/4 | 113.70 | 50.4 | 91.0 | 1,182.8 | |
| 117 | 540 | 10 | 4/4 | 116.52 | 40.4 | 80.2 | 1,190.3 | |
| 117 | 540 | 25 | 5/4 | 114.84 | --- | --- | --- | Cable break |
| 119 | 645 | 0 | 1/6 | 168.52 | 26.5 | 124.0 | 973.8 | |
| 120 | 750 | 0 | 2/5 | 231.46 | 18.5 | 187.0 | 993.3 | |
| 121 | 840 | 0 | 3/6 | 287.00 | 14.1 | 204.0 | 891.8 | |
| 121 | 840 | 10 | 4/6 | 286.62 | 14.2 | 200.0 | 853.7 | |
| 121 | 840 | 25 | 5/6 | 286.86 | 13.9 | 211.0 | 906.8 | |
| 122 | 1,000 | 0 | 1/10 | 395.01 | 9.8 | 222.0 | 757.3 | |
| 124 | 1,500 | 0 | 2/9 | 765.26 | 4.7 | 296.0 | 530.7 | |
| 125 | 2,000 | 0 | 3/10 | 1,161.58 | 2.9 | 331.0 | 381.8 | |
| 127 | 3,000 | 0 | 4/10 | 1,991.10 | 1.7 | 179.0 | 121.3 | |
| 129 | 3,800 | 0 | 5/10 | 2,676.86 | 1.02 | 240.0 | 83.6 | |
| 130 | 5,000 | 0 | 11.90 | --- | 0.89 | 365.0 | 134.0 | Bearing 183° |
| 131 | 6,800 | 0 | 11.93 | --- | 0.61 | 372.0 | 112.0 | Bearing 183° |
| 132 | 12,000 | 0 | 48.03 | --- | 0.48 | --- | --- | Bearing 263° |

TABLE 3.3. --- Results of side-on measurements, line 2

| Station | Ground Range (ft) | Elevation (ft) | Bearing (deg) | Recorder (Sys/Ch) | Arrival Time (msec) | Maximum Overpressure (psi) | Positive Duration (msec) | Overpressure Impulse (psi-msec) |
|--|-------------------------|-------------------|------------------|----------------------|---------------------------|----------------------------------|--------------------------------|---------------------------------------|
| 205 | 120 | 0 | 98 | 6/1 | 9.18 | 1,160.0 | 11.0 | 1,725.1 |
| 206 | 180 | 0 | 90 | 7/1 | 16.40 | 696.0 | 12.6 | 1,840.6 |
| 207 | 270 | 0 | 98 | 6/2 | 31.26 | 358.0 | 87.1 | 3,540.0 |
| 209 | 340 | 0 | 147 | 7/2 | 46.21 | 186.0 | 85.0 | 2,463.9 |
| 210 | 380 | 0 | 127 | 6/3 | 57.60 | 124.5 | 73.7 | 2,008.3 |
| 211 | 420 | 0 | 98 | 7/3 | 70.63 | 91.9 | 82.20 | 1,671.6 |
| 215 | 500 | 0 | 73 | 6/4 | 101.88 | 61.9 | 95.0 | 1,196.7 |
| 217 | 540 | 0 | 98 | 7/4 | 108.55 | 41.6 | 127.0 | 1,236.9 |
| 221 | 840 | 0 | 90 | 6/5 | 286.30 | 14.2 | 227.0 | 928.9 |
| 222 | 1,000 | 0 | 92 | 7/5 | 395.77 | 10.2 | 142.0 | 463.6 |
| 223 | 1,110 | 0 | 98 | 6/6 | 474.55 | 7.9 | 121.0 | 341.4 |
| 224 | 1,430 | 0 | 98 | 7/6 | 712.47 | 5.5 | 250.0 | 563.4 |
| 226 | 2,300 | 0 | 102 | 05-23 | --- | 3.2 | --- | --- |
| 228 | 3,200 | 0 | 98 | 02-17 | --- | 1.75 | 367.0 | 263.0 |
| Results of free-field support measurements | | | | | | | | |
| 117 | 540 | 0 | 260 | 12.03 | --- | 32.5 | 179.0 | 1,760.0 |
| 217 | 540 | 0 | 86 | 6/9 | 117.93 | 47.8 | 110.0 | 1,132.5 |
| 218 | 615 | 0 | 94 | 7/9 | 150.88 | 36.3 | 153.0 | 1,109.6 |
| 219 | 645 | 0 | 92 | 6/10 | 164.71 | 21.4 | 159.0 | 1,008.5 |
| 121 | 840 | 0 | 242 | 25.08 | --- | 15.0 | 209.0 | 1,142.0 |

TABLE 3.4. -- Results of dynamic pressure measurements

| Station | Range (ft) | Recorder (Sys/Ch) | Maximum Dynamic Pressure (psi) | Dynamic Pressure Impulse (psi-msec) | Elevation (ft) | Remarks |
|---------|---------------|----------------------|---|--|-------------------|-------------------------|
| 105 | 120 | 5/1-5/2 | --- | --- | 2 | Total-head gage lost |
| 106 | 180 | 1/2-1/3 | --- | --- | 2 | Side-on gage lost |
| 107 | 270 | 2/2-2/3 | 550.0 | 3,137.7 | 2 | |
| 108 | 325 | 3/2-3/3 | 345.0 | 1,962.3 | 2 | |
| 112 | 425 | 4/2-4/3 | 120.0 | 1,152.8 | 2 | |
| 114 | 480 | 1/4-1/5 | 112.0 | 967.4 | 2 | |
| 117 | 540 | 3/4-3/5 | 80.0 | 988.0 | 2 | |
| 117 | 540 | 4/4-4/5 | 26.0 | 551.8 | 10 | |
| 117 | 540 | 5/4-5/5 | --- | --- | 25 | Total-head gage lost |
| 119 | 645 | 1/6-1/9 | 13.0 | 506.3 | 2 | |
| 120 | 750 | 2/5-2/6 | 5.5 | 185.1 | 2 | |
| 121 | 840 | 3/6-3/9 | 4.5 | 110.7 | 2 | |
| 121 | 840 | 4/6-4/9 | 4.3 | 170.2 | 10 | |
| 121 | 840 | 5/6-5/9 | 3.5 | 155.0 | 25 | |

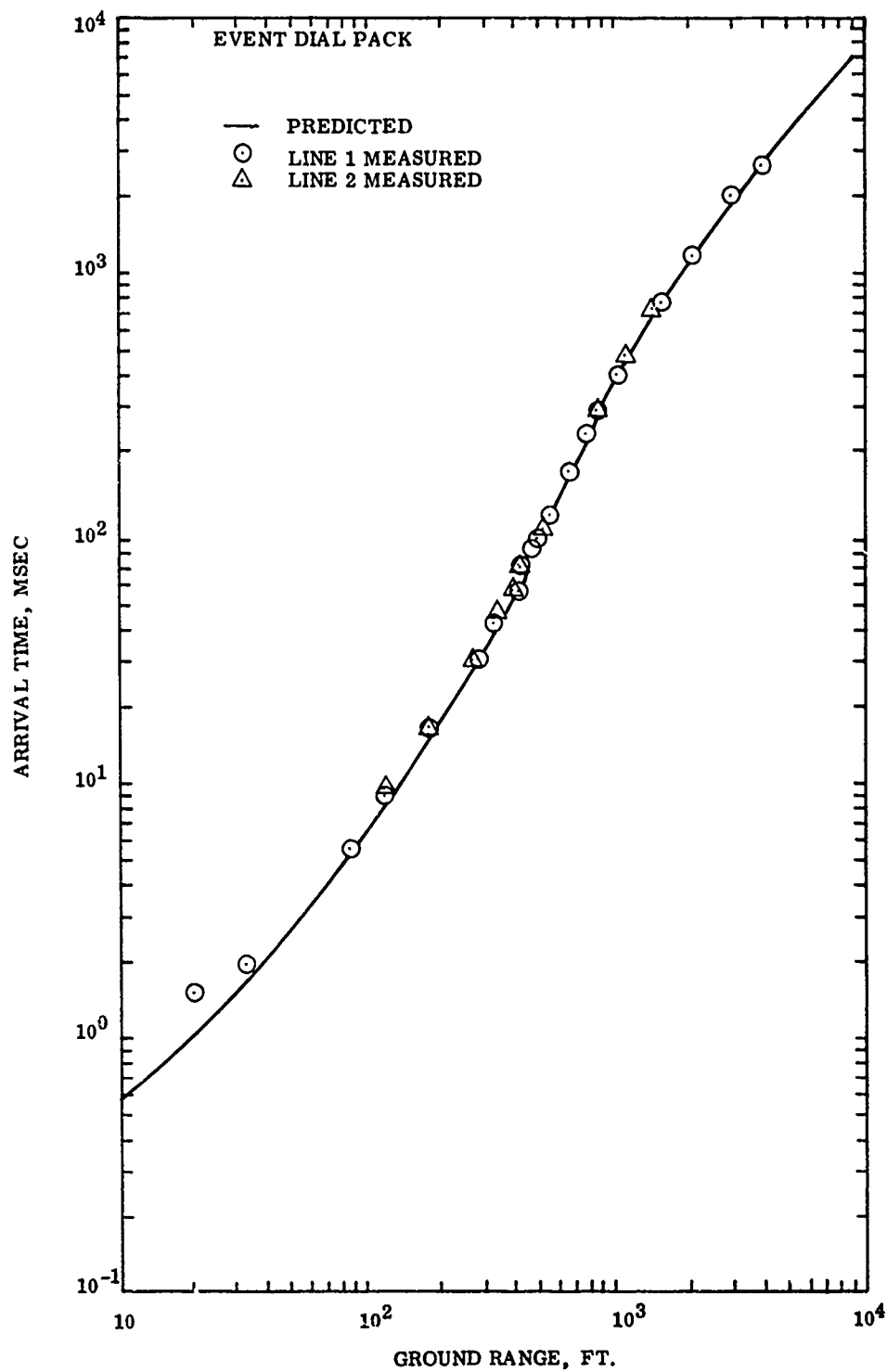


Figure 3.3. --Arrival time versus ground range.

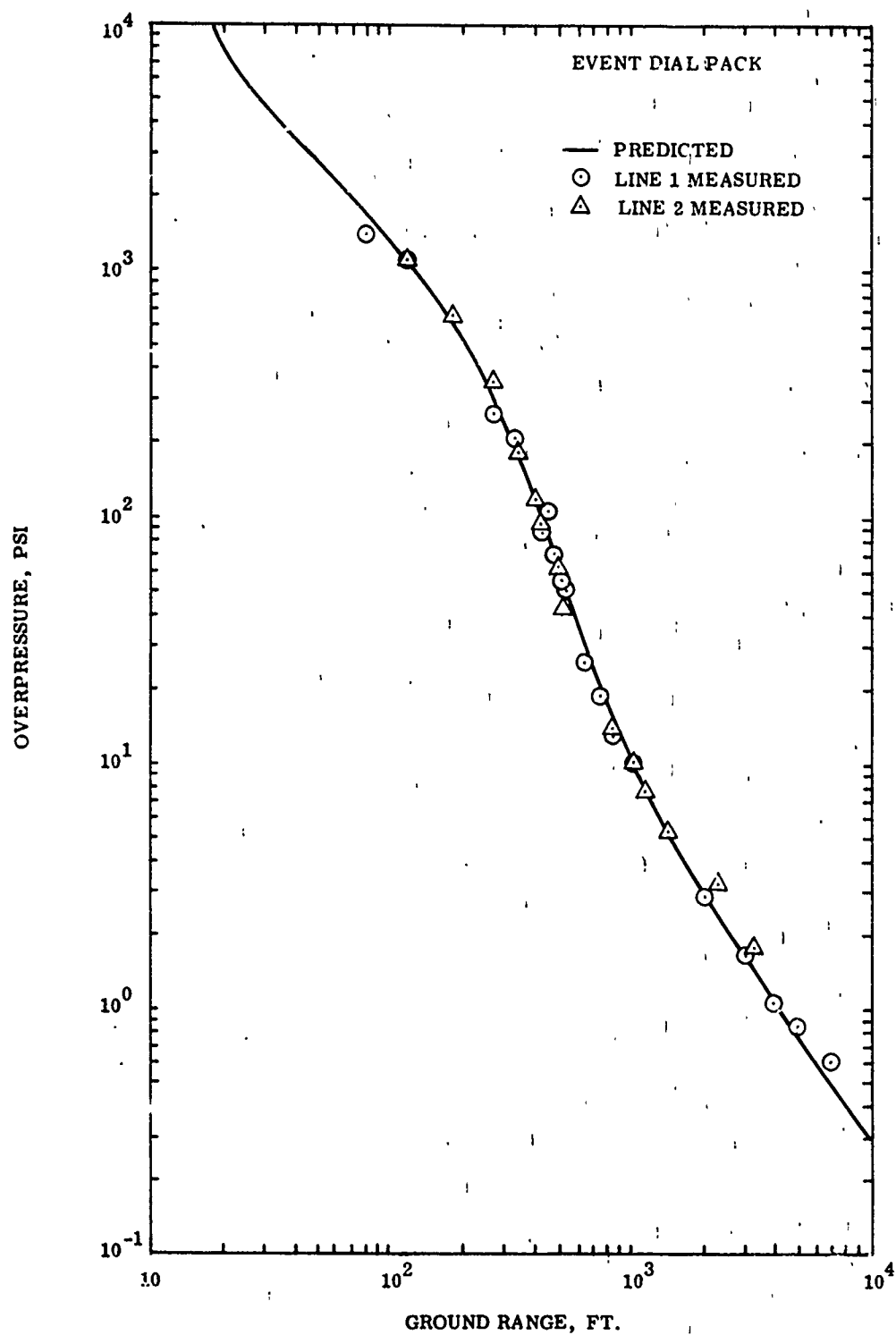


Figure 3.4.--Maximum overpressure versus ground range.

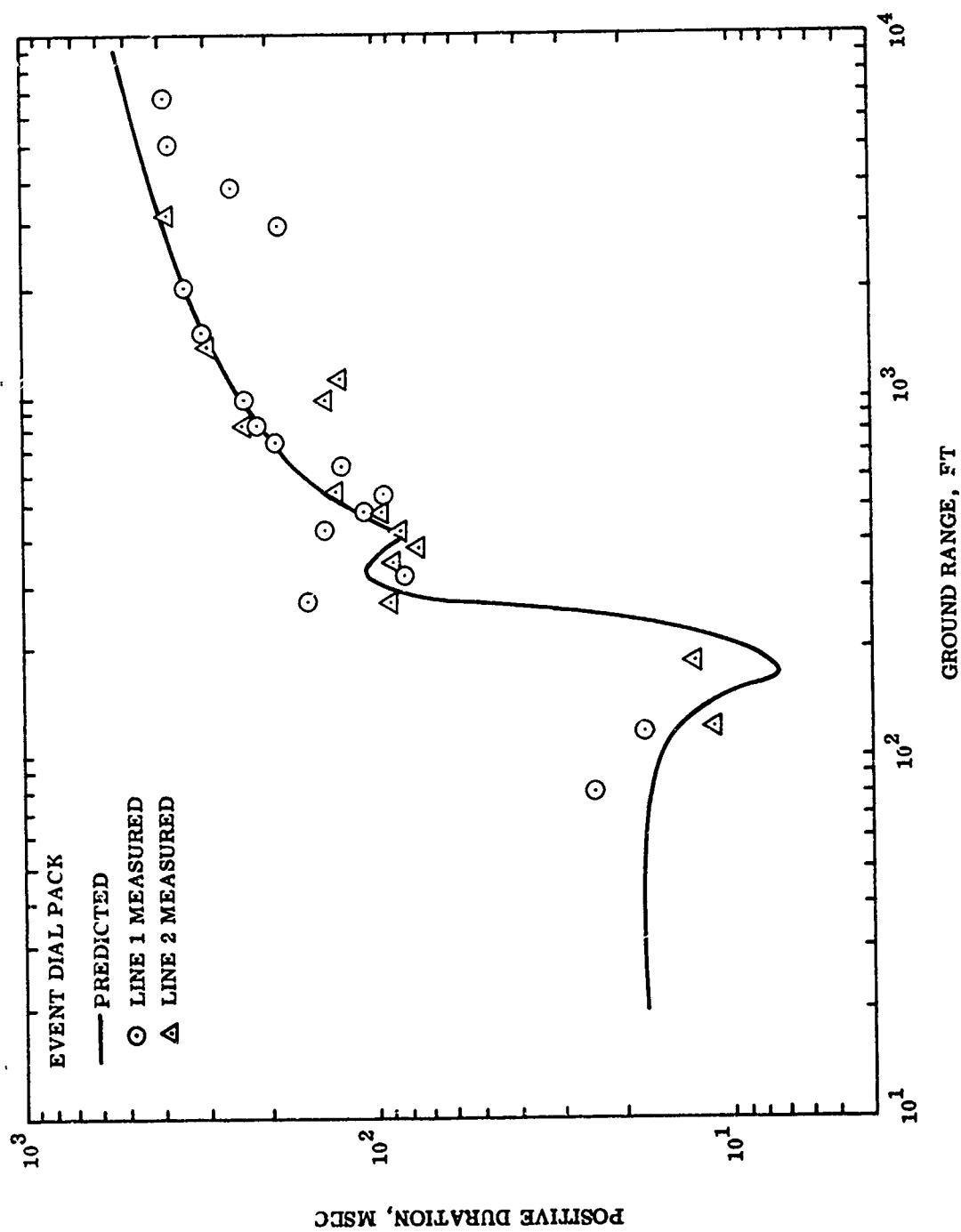


Figure 3.5. --Positive phase duration versus ground range.

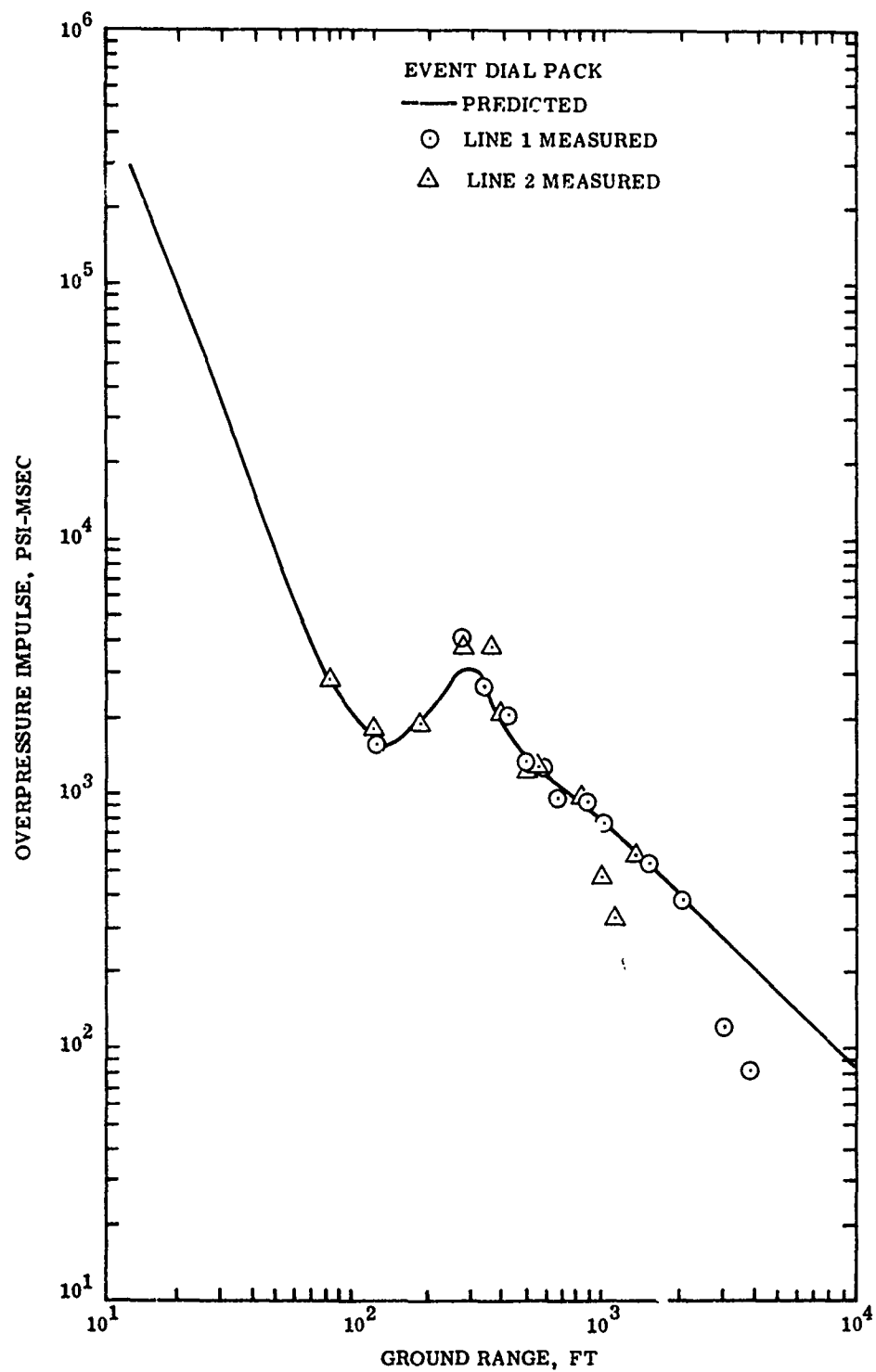


Figure 3.6. --Overpressure impulse versus ground range.

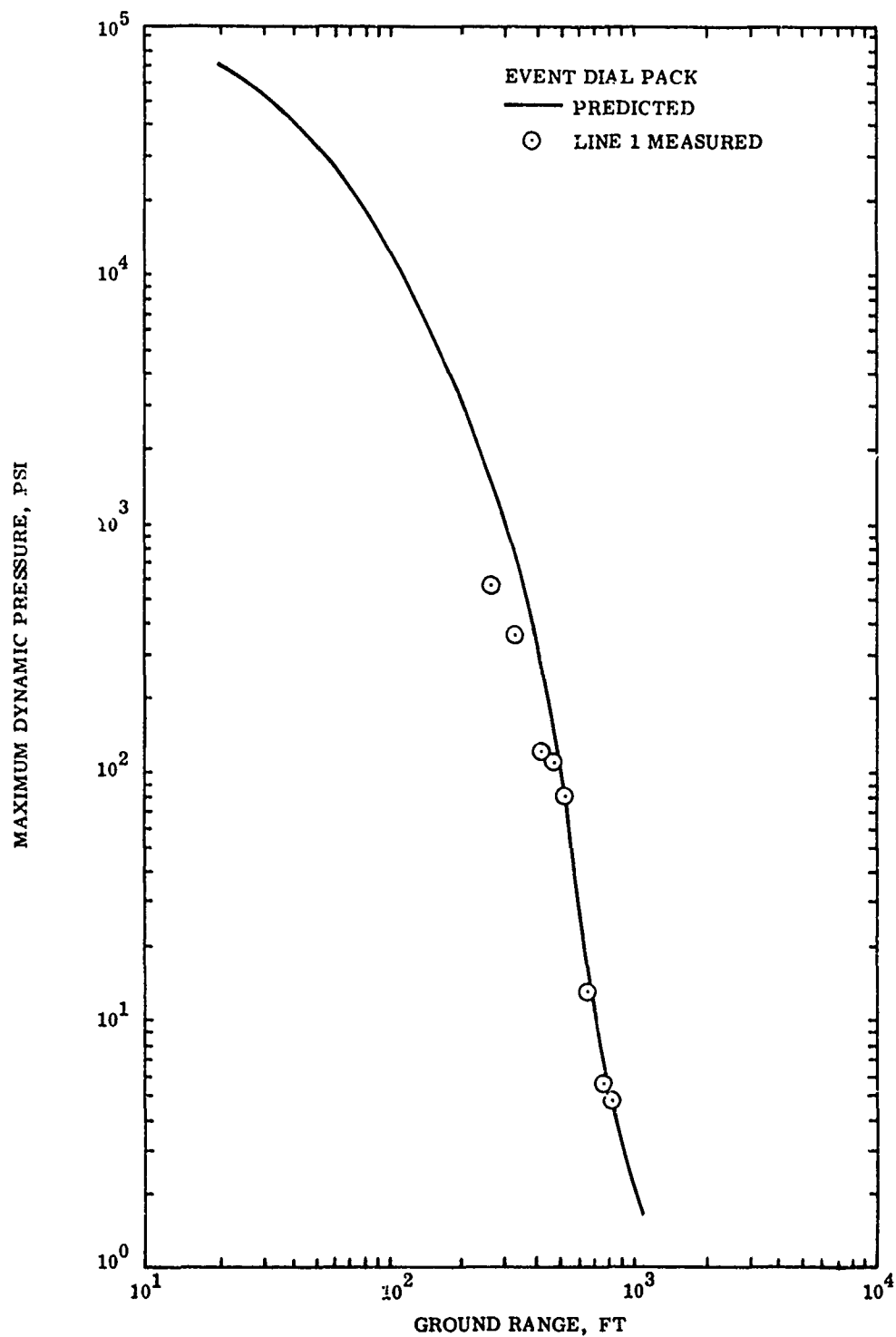


Figure 3.7. --Maximum dynamic pressure versus ground range.

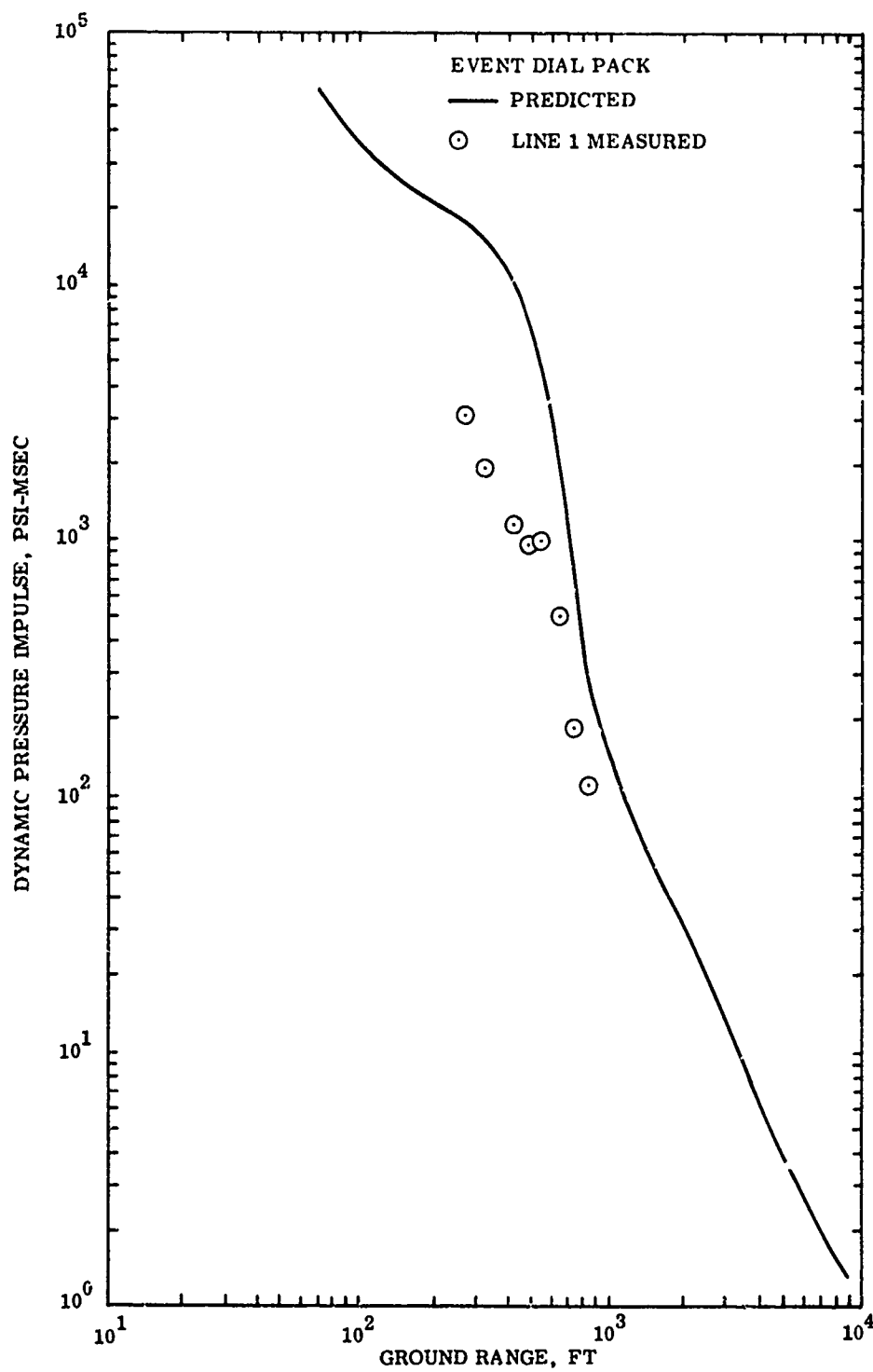


Figure 3.8. --Dynamic pressure impulse versus ground range.

CHAPTER 4

DISCUSSION

4.1. BLAST ANOMALIES. Pressure gages installed at similar radial distances, but on different azimuths, recorded entirely different pressure-time histories and thus indicated the nonsymmetry of the blast wave (see figure 4.1 for time-history comparisons). It was first thought that the cause of the nonclassical wave shapes was due to fireball anomalies and jetting; however, it now appears that some of these unusual wave shapes may be part of the phenomena, since they are also recorded in areas where there are no indications of jetting. This is reported by Project 102, Blast Anomalies Studies, which reported luminous precursor jets at azimuths of 5° , 60.5° , 232° and 265° ; nonluminous jets at 140° and 270° and other perturbations unrelated to the jetting action are given in reference 5.

4.2. DATA COMPARISON WITH PREDICTIONS AND PRAIRIE FLAT.

The blast predictions have been presented as a solid curve for each of the parameters in chapter 3. The comparison of the DIAL PACK overpressure data from the primary line (line 1) with PRAIRIE FLAT is presented in figures 4.2 through 4.5.

The measured values of arrival time are longer than predicted, although they agree well with those of the PRAIRIE FLAT Event. The predictions did not include the PRAIRIE FLAT data because of the many disturbed wave shapes and lower maximum overpressure measured on that event.

The measured overpressure from both lines 1 and 2 show little divergence from those predicted or from the PRAIRIE FLAT curve of maximum overpressure versus ground range. What scatter does exist occurs at the high and low pressure areas of the curve. With these exceptions, the DIAL PACK data indicates less scatter than that obtained on prior events utilizing the same charge placement and configuration.

Considerable scatter is seen in the positive duration data as related to the predicted curve. This scatter is more predominant on line 1 than line 2; especially at the four distant stations, 3,000 feet through 6,800 feet. Two of the

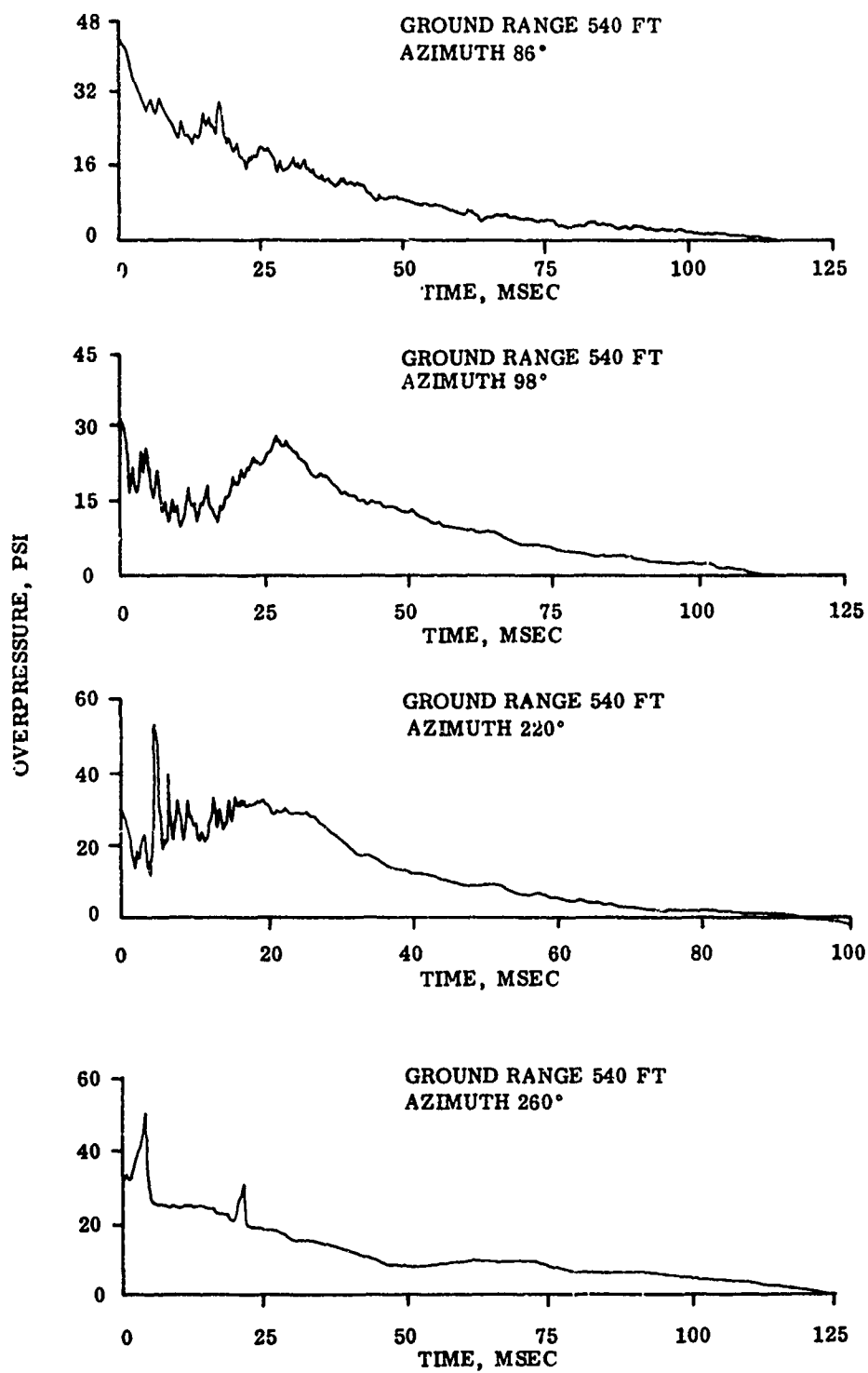


Figure 4.1. --Pressure time record comparison.

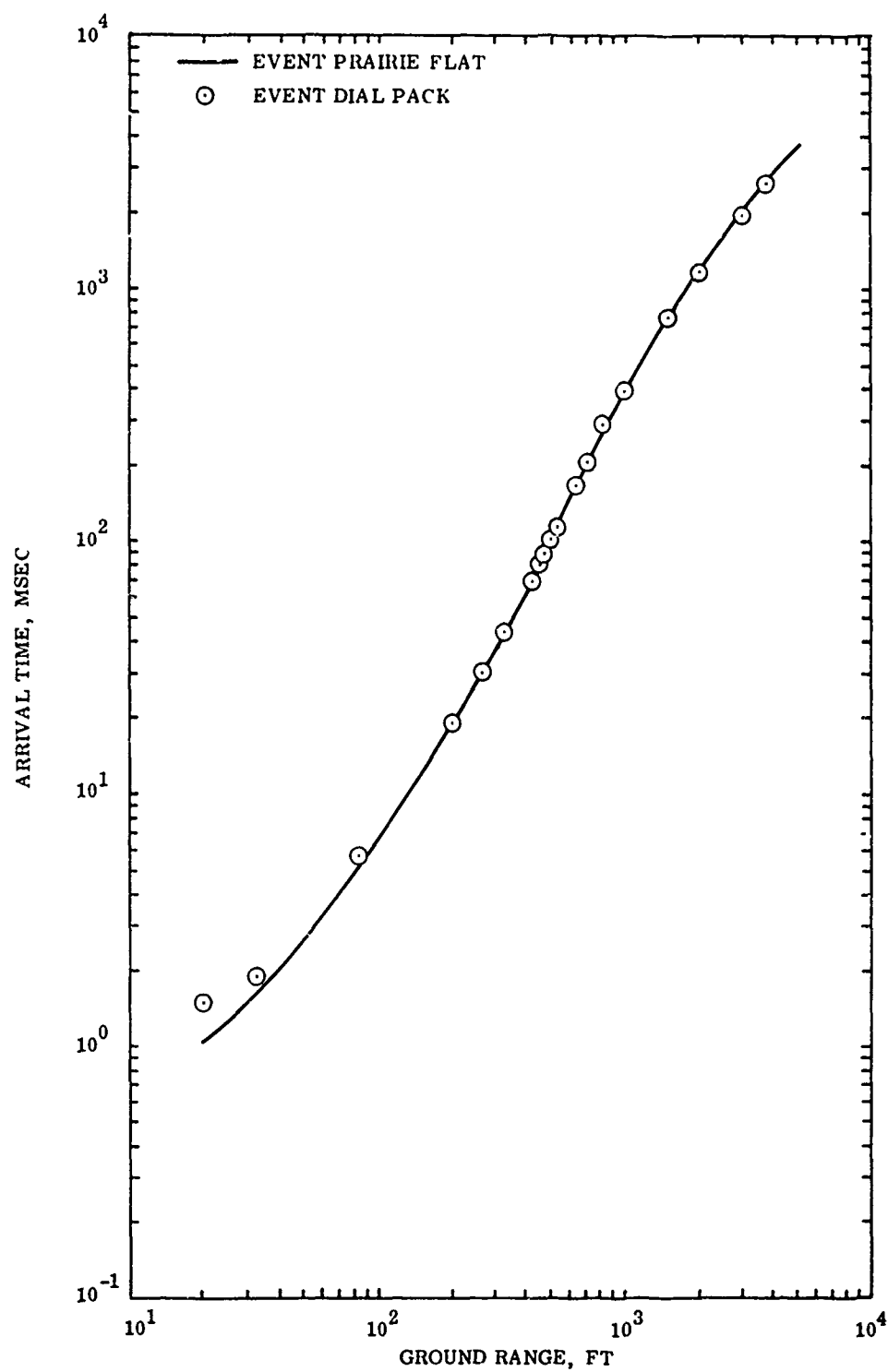


Figure 4.2. --Arrival time comparison between PRAIRIE FLAT and DIAL PACK.

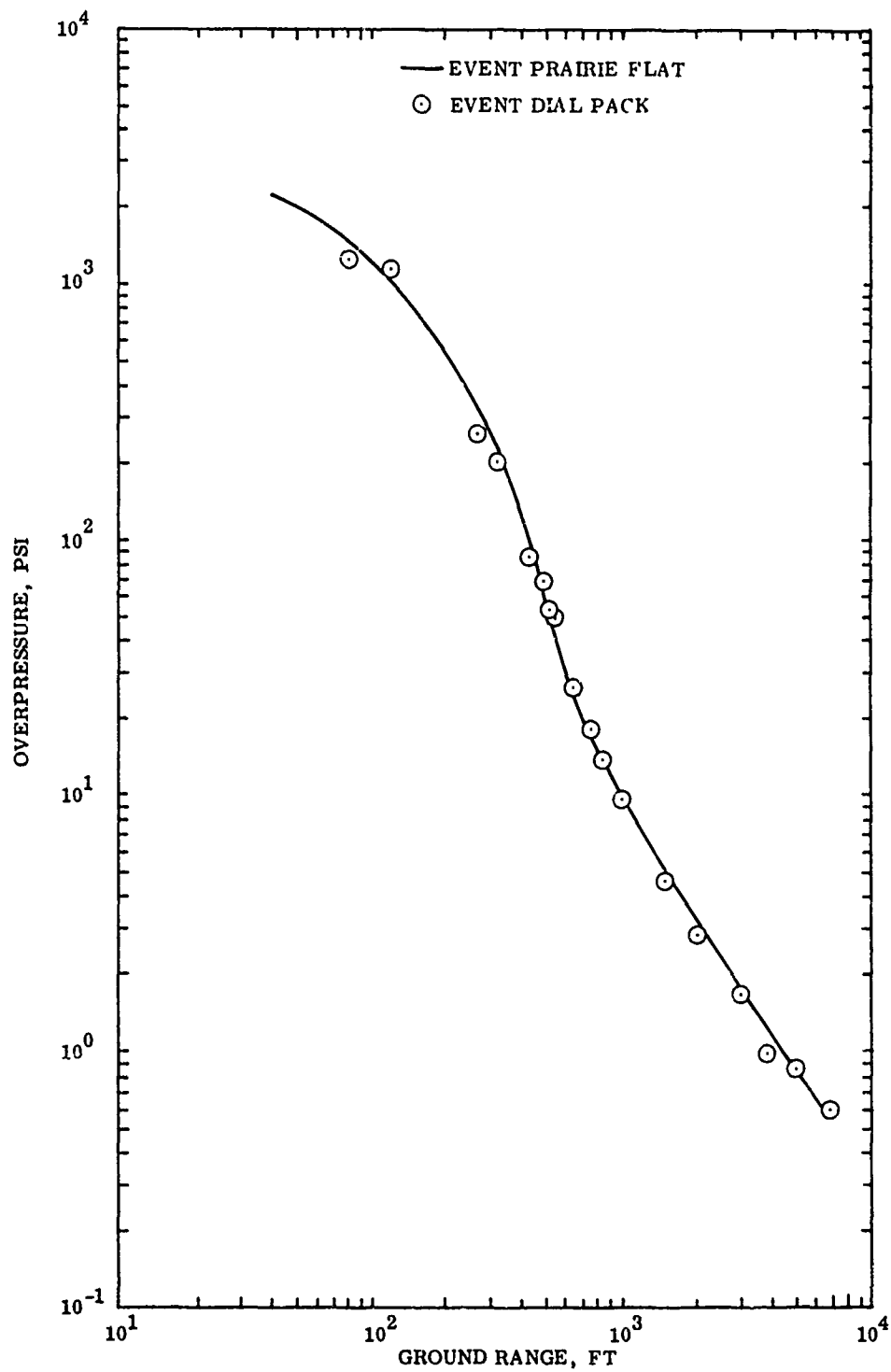


Figure 4.3. --Overpressure comparison between PRAIRIE FLAT and DIAL PACK.

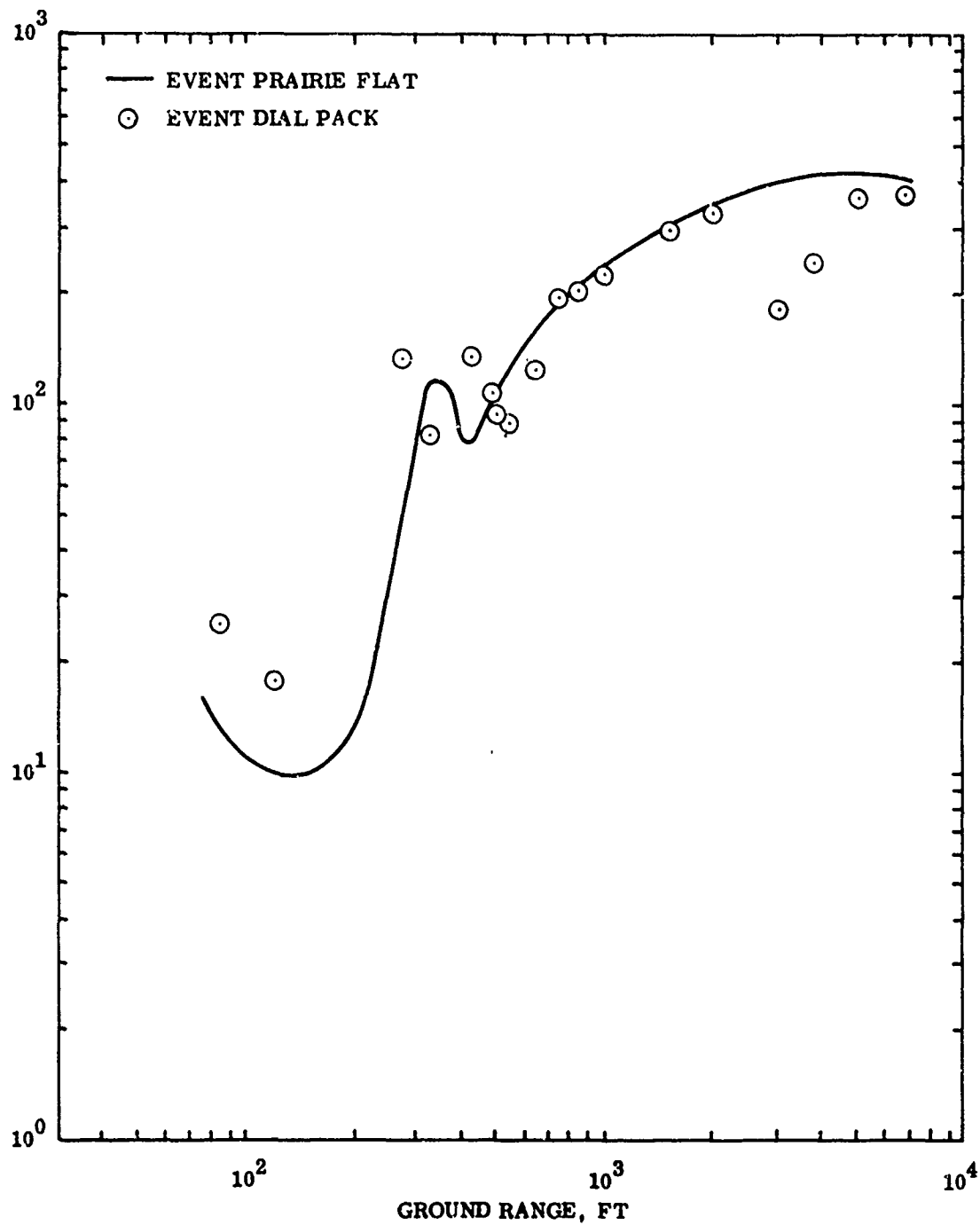


Figure 4.4. --Positive duration comparison between PRAIRIE FLAT and DIAL PACK.

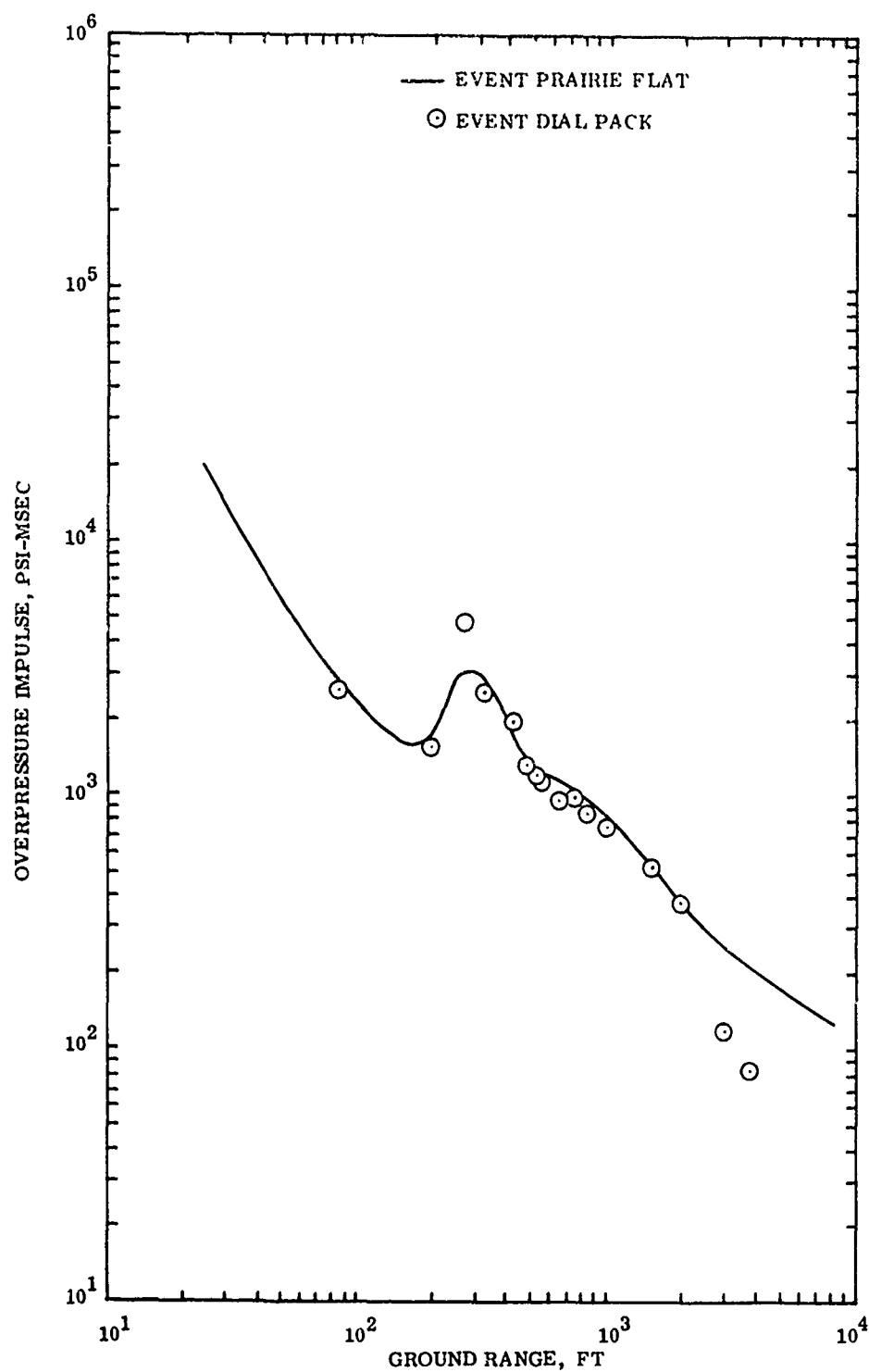


Figure 4.5. --Overpressure impulse comparison between PRAIRIE FLAT and DIAL PACK.

stations were instrumented with electronic gages and two with self-recording gages. Since all systems yielded lower readings than anticipated, it would seem that the shorter durations are a function of the phenomena. No explanation is offered for the longer durations measured at 270 feet and 425 feet on line 1.

On line 2, two very classical waveforms were recorded at 1,000 feet and 1,100 feet; however, the durations are much shorter than predicted.

In comparison with the PRAIRIE FLAT data, it is seen that the two distant stations come within the band of experimental accuracy in relation to the curve. The four other stations (line 1) that are "out" in relation to the predicted curve are also deviates from the PRAIRIE FLAT curve.

The measured overpressure impulse follows the same trend as established by the positive duration. Excellent agreement exists overall with the predicted curve. Close examination of the comparison with PRAIRIE FLAT shows an impulse 5 to 10 percent less than that experienced with PRAIRIE FLAT over the majority of the ground ranges instrumented.

The measured dynamic pressure compares favorably with the predicted data over the 5- to 100-psi range. At higher pressures, the measurements are lower than the predictions. The AFWL theoretical data comprises the predicted curve from the 1-psi region and above; below that level, empirical data was used. DIAL PACK results, related to previous shots in figure 4.10 (PRAIRIE FLAT and DISTANT PLAIN 6), show excellent agreement.

Dynamic pressure-impulse results were lower than the predicted curve over the entire range of measurements. In this case, the predicted curve was developed using the AFWL theory in the region of 400 psi-msec and above where the accuracy of the data is the best; below this level, empirical data was used. When related to PRAIRIE FLAT and DISTANT PLAIN, figure 4.11, it is observed that DIAL PACK is generally in the center of the group of data points. Consistency between measured data from different events is apparent.

The fact that the measurements of DIAL PACK are less than the theory for the dynamic pressure impulse and for the dynamic pressure above 200 psi may be attributed to the severe environmental conditions seen by the measurement system and the increase in error band which would result.

4.3. SCALING. Comparison with prior shots is made on the basis of a common standard; in blast work the standard, which has been established for scaling, is a 1-pound charge at sea-level conditions where the ambient pressure is 14.7 psi and the ambient temperature is 15°C. The standard scaling relationships are as follows:

$$S_p = 14.7/P_o$$

$$S_d = \left[\frac{P_o}{14.7 (W)} \right]^{1/3}$$

$$S_t = \left[\frac{T_o + 273}{288} \right]^{1/2} S_d$$

$$S_I = (S_p) (S_t),$$

where

S_p = scaling factor for pressure

S_d = scaling factor for distance

S_t = scaling factor for time

S_I = scaling factor for impulse

P_o = ambient atmosphere pressure at the surface or elevation of interest

W = yield in pounds

T_o = measured temperature in degrees centigrade.

The scaling factors for the DIAL PACK Event are as follows:

$$S_p = 1.0833$$

$$S_d = 0.0097$$

$$S_t = 0.0100$$

$$S_I = 0.0108$$

The scaled parameters versus ground range are presented in figures 4.6 through 4.11 and in tables 4.1 and 4.2.

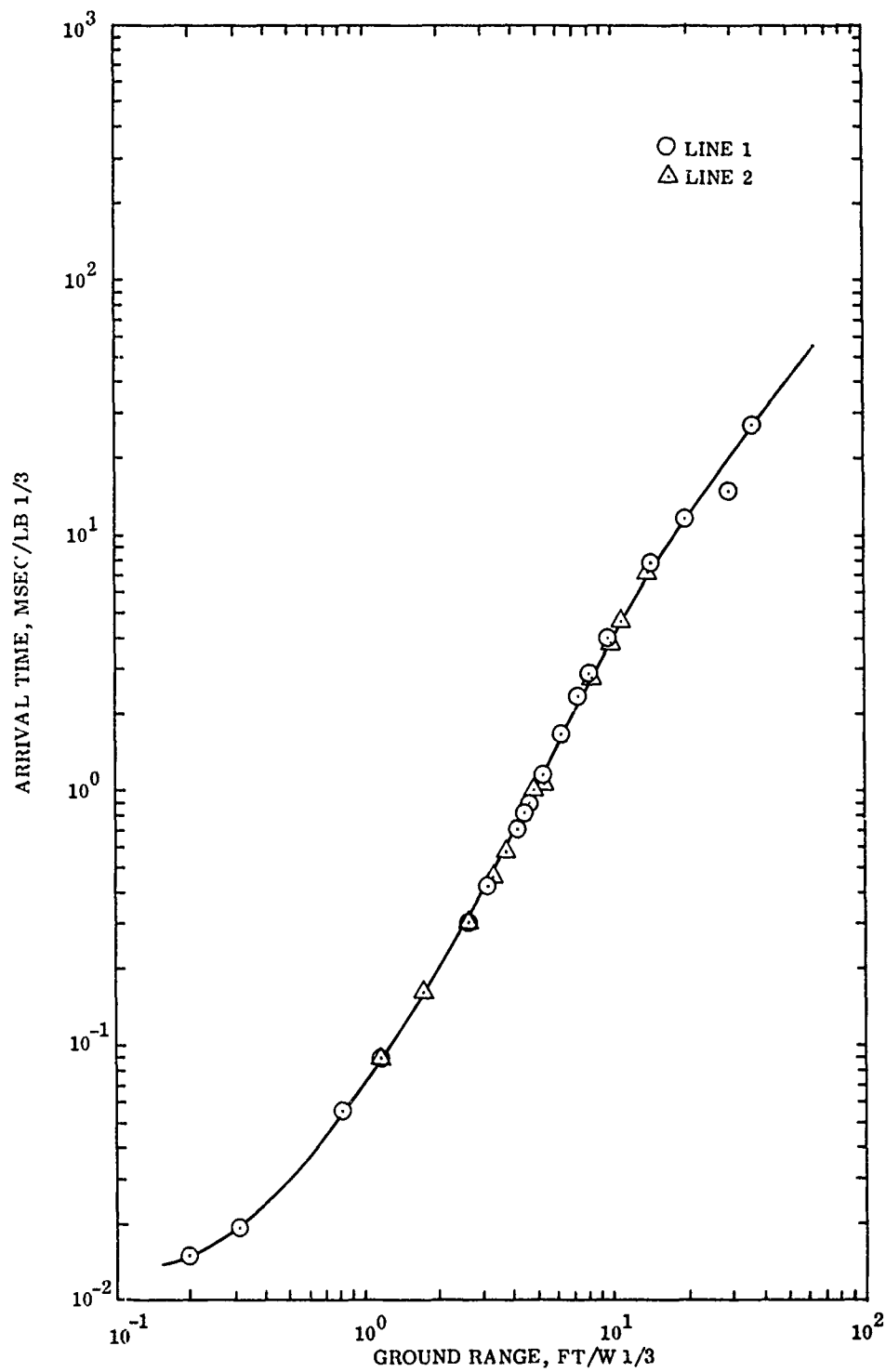


Figure 4.6. --Arrival time scaled to 1 lb. sea-level condition.

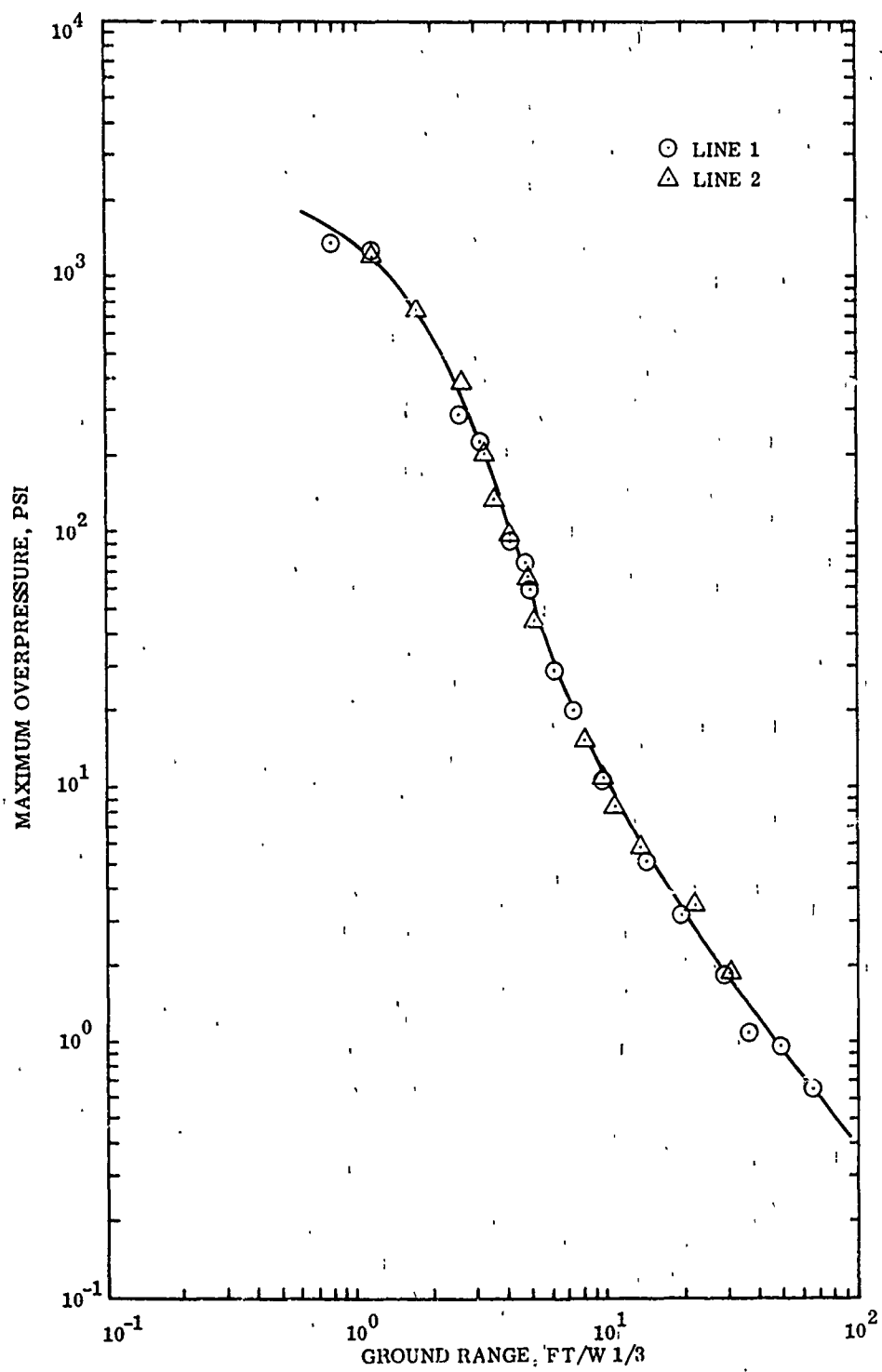


Figure 4.7. --Maximum overpressure scaled to 1 lb. sea-level condition.

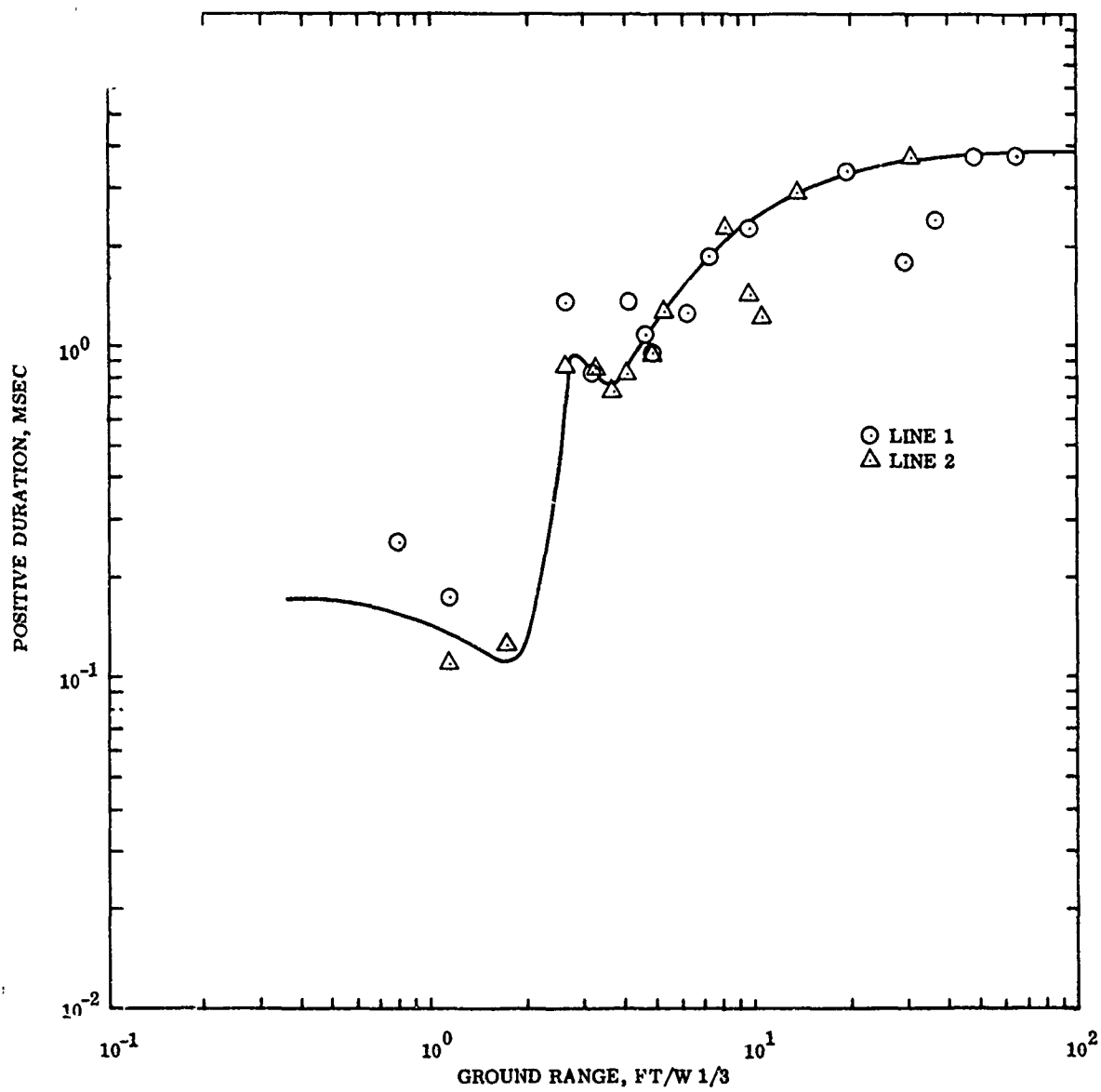


Figure 4.8. --Positive duration scaled to 1 lb. sea-level condition.

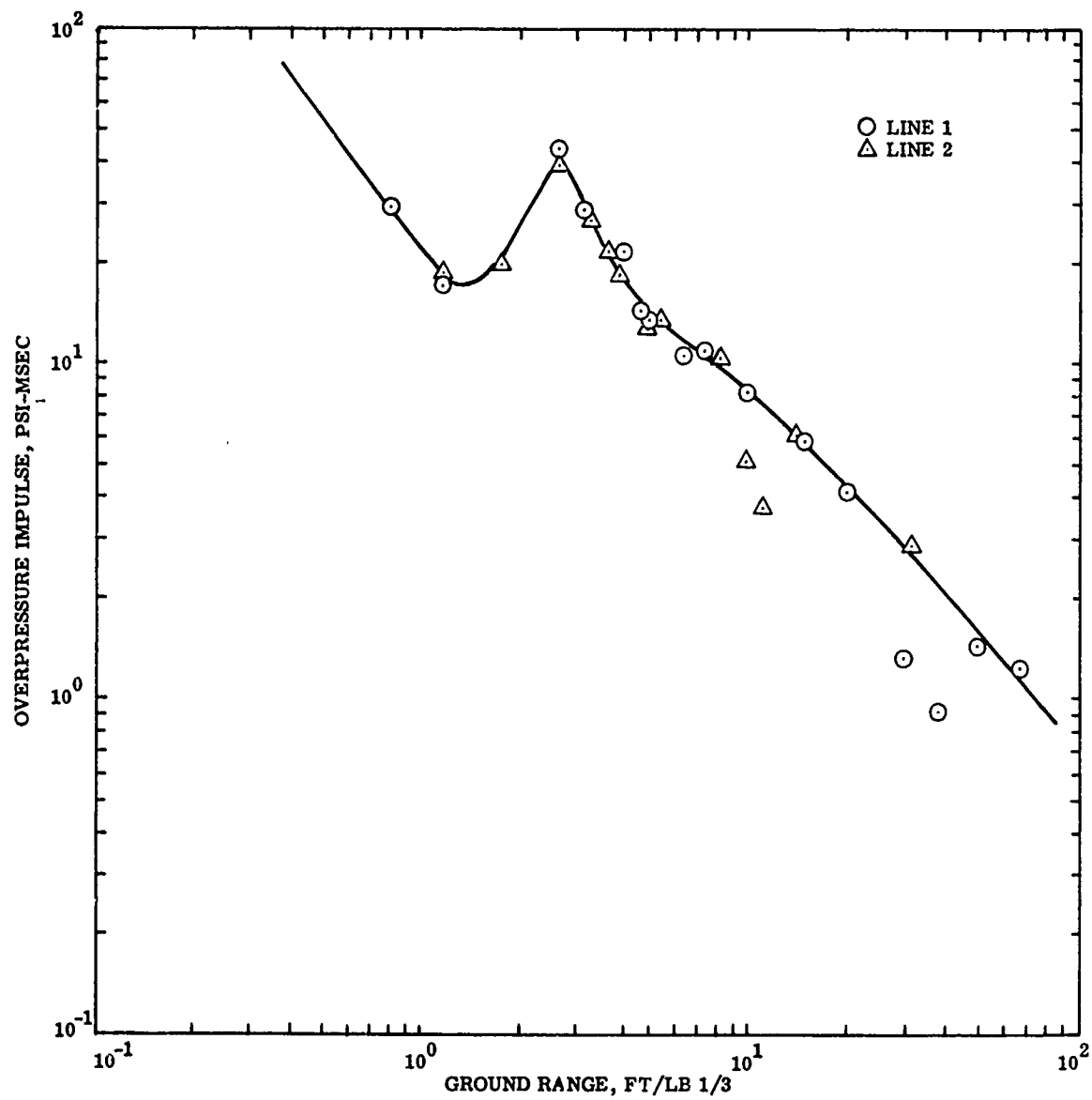


Figure 4.9. --Positive overpressure impulse scaled to 1 lb. sea-level condition.

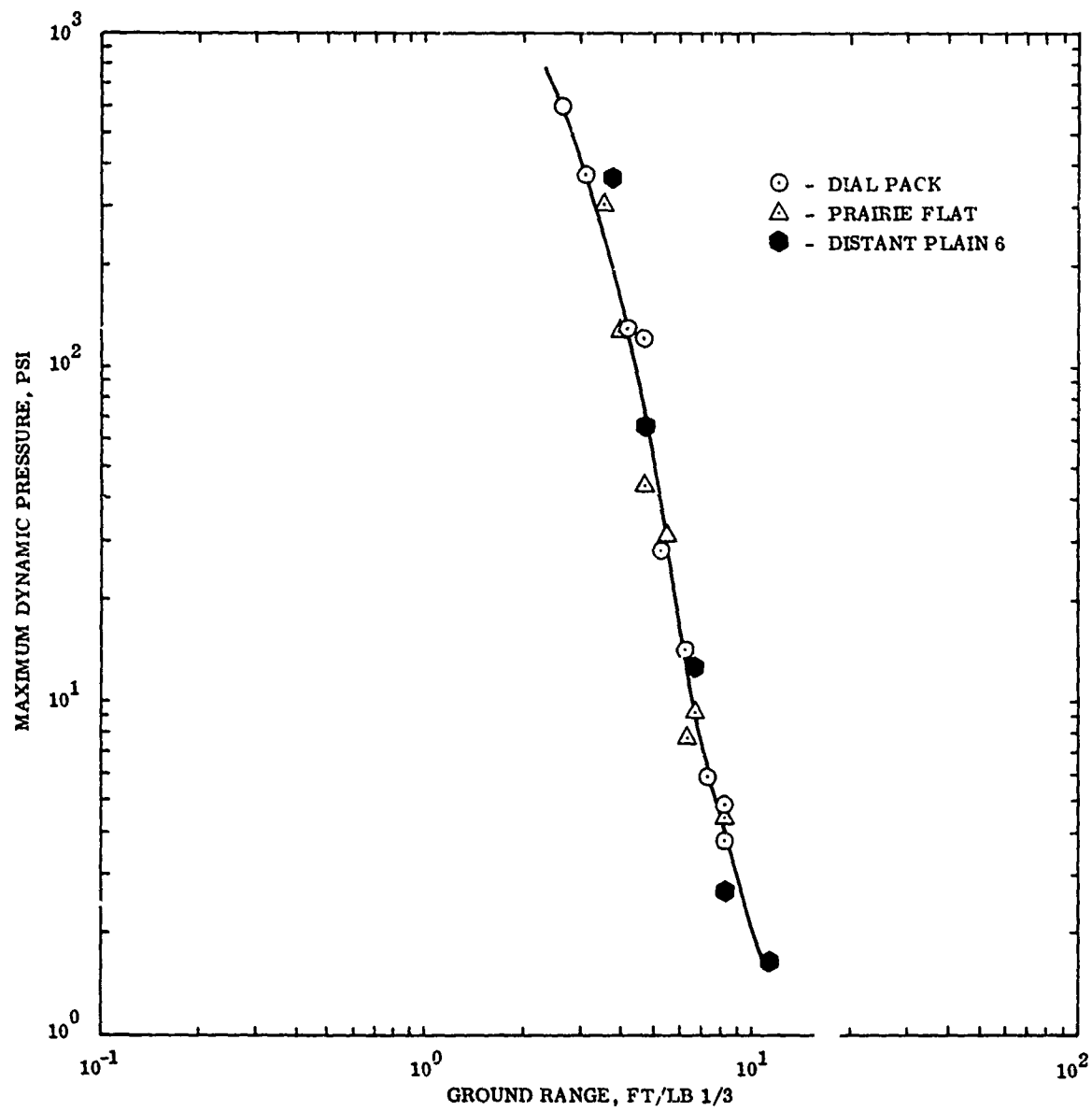


Figure 4.10. --Dynamic pressure scaled to 1 lb. sea-level condition.

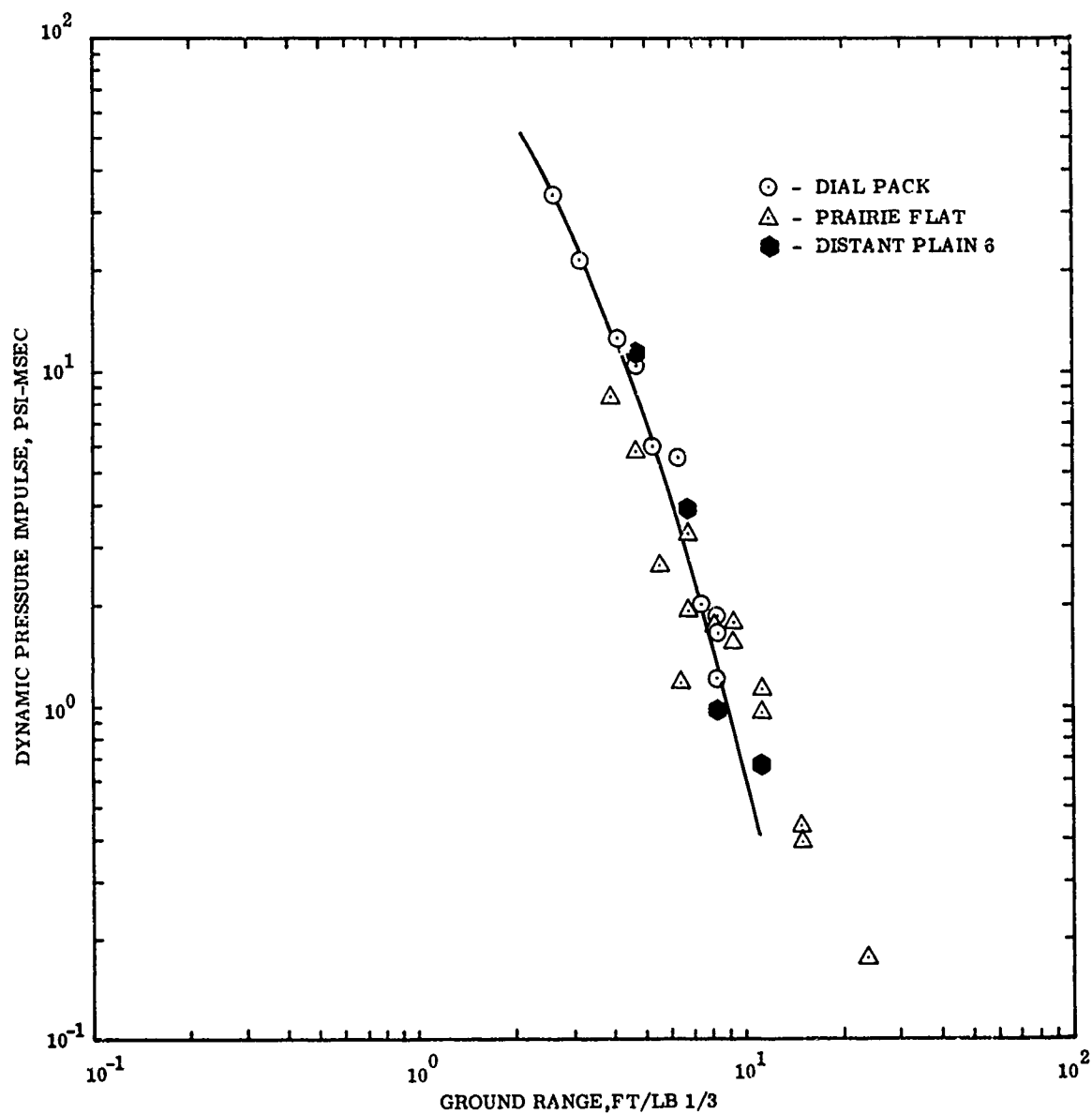


Figure 4.11. --Dynamic pressure impulse scaled to 1 lb. sea-level condition.

TABLE 4.1. -- Measured overpressure data scaled to 1 lb. sea-level condition.

| <u>Station Number</u> | <u>Ground Range (ft)</u> | <u>Arrival Time (msec)</u> | <u>Overpressure (psi)</u> | <u>Positive Duration (msec)</u> | <u>Overpressure Impulse (psi-msec)</u> |
|---------------------------|----------------------------------|------------------------------------|-------------------------------|---|--|
| A. Line 1 Data | | | | | |
| 102 | 0.19 | 0.01 | --- | --- | --- |
| 102A | 0.19 | 0.01 | --- | --- | --- |
| 103 | 0.31 | 0.01 | --- | --- | --- |
| 104 | 0.80 | 0.05 | 1,365.0 | 0.25 | 28.99 |
| 105 | 1.16 | 0.09 | 1,273.0 | 0.17 | 17.07 |
| 106 | 1.74 | 0.08 | --- | --- | --- |
| 107 | 2.61 | 0.30 | 286.0 | 1.35 | 43.23 |
| 108 | 3.15 | 0.42 | 226.4 | 0.81 | 28.27 |
| 112 | 4.12 | 0.71 | 95.3 | 1.34 | 21.32 |
| 113 | 4.46 | 0.82 | --- | --- | --- |
| 114 | 4.65 | 0.89 | 76.8 | 1.08 | 14.34 |
| 116 | 4.94 | 1.00 | 60.0 | 0.93 | 13.50 |
| 117 | 5.23 | 1.13 | 54.6 | 0.91 | 12.77 |
| 117 | 5.23 | 1.16 | 43.8 | 0.80 | 12.86 |
| 117 | 5.23 | 1.14 | --- | --- | --- |
| 119 | 6.25 | 1.68 | 28.7 | 1.24 | 10.52 |
| 120 | 7.27 | 2.31 | 20.0 | 1.87 | 10.73 |
| 121 | 8.14 | 2.87 | 15.3 | 2.04 | 9.63 |
| 121 | 8.14 | 2.86 | 15.4 | 2.00 | 9.22 |
| 121 | 8.14 | 2.86 | 15.0 | 2.11 | 9.79 |
| 122 | 9.70 | 3.95 | 10.6 | 2.22 | 8.18 |
| 124 | 14.55 | 7.65 | 5.09 | 2.96 | 5.73 |
| 125 | 19.40 | 11.61 | 3.14 | 3.31 | 4.12 |
| 127 | 29.10 | 19.91 | 1.84 | 1.79 | 1.31 |
| 129 | 36.86 | 26.76 | 1.10 | 2.40 | 0.903 |
| 130 | 48.50 | --- | 0.964 | 3.65 | 1.45 |
| 131 | 65.96 | --- | 0.661 | 3.72 | 1.21 |
| 132 | 116.4 | --- | 0.520 | --- | --- |
| B. Line 2 Data | | | | | |
| 205 | 1.16 | 0.09 | 1,257.0 | 0.11 | 18.63 |
| 206 | 1.74 | 0.16 | 754.0 | 0.12 | 19.88 |
| 207 | 2.61 | 0.31 | 388.0 | 0.87 | 38.23 |
| 209 | 3.29 | 0.46 | 201.5 | 0.85 | 26.61 |
| 210 | 3.68 | 0.57 | 135.0 | 0.73 | 21.69 |
| 211 | 4.07 | 0.70 | 99.6 | 0.82 | 18.05 |
| 215 | 4.85 | 1.01 | 67.1 | 0.95 | 12.92 |
| 217 | 5.23 | 1.08 | 45.1 | 1.27 | 13.36 |
| 221 | 8.14 | 2.86 | 15.4 | 2.27 | 10.03 |
| 222 | 9.70 | 3.95 | 11.0 | 1.42 | 5.01 |
| 223 | 10.76 | 4.74 | 8.56 | 1.21 | 3.69 |

TABLE 4.1.-- (Continued)

| <u>Station Number</u> | <u>Ground Range (ft)</u> | <u>Arrival Time (msec)</u> | <u>Overpressure (psi)</u> | <u>Positive Duration (msec)</u> | <u>Overpressure Impulse (psi-msec)</u> |
|---------------------------|----------------------------------|------------------------------------|-------------------------------|---|--|
| 224 | 13.87 | 7.12 | 5.96 | 2.90 | 6.08 |
| 226 | 22.31 | --- | 3.47 | --- | --- |
| 228 | 31.04 | --- | 1.90 | 3.67 | 2.84 |

C. Free-field Support Data

| | | | | | |
|-----|------|------|------|------|-------|
| 117 | 5.23 | --- | 35.2 | 1.79 | 19.00 |
| 217 | 5.23 | 1.17 | 51.8 | 1.10 | 12.23 |
| 218 | 5.91 | 1.50 | 39.3 | 1.53 | 11.98 |
| 219 | 6.25 | 1.64 | 23.2 | 1.59 | 10.89 |
| 121 | 8.14 | --- | 16.2 | 2.09 | 12.33 |

TABLE 4.2. --Measured dynamic pressure data scaled to 1 lb. sea-level conditions

| <u>Station Number</u> | <u>Ground Range (ft)</u> | <u>Maximum Dynamic Pressure (psi)</u> | <u>Dynamic Pressure Impulse (psi-msec)</u> |
|---------------------------|----------------------------------|---|--|
| 105 | 1.16 | --- | --- |
| 106 | 1.74 | --- | --- |
| 107 | 2.61 | 596.0 | 33.89 |
| 108 | 3.15 | 374.0 | 21.19 |
| 112 | 4.12 | 130.0 | 12.45 |
| 114 | 4.65 | 121.3 | 10.45 |
| 117 | 5.23 | 86.7 | 10.67 |
| 117 | 5.23 | 28.2 | 5.96 |
| 117 | 5.23 | --- | --- |
| 119 | 6.25 | 14.1 | 5.47 |
| 120 | 7.27 | 5.96 | 2.00 |
| 121 | 8.14 | 4.87 | 1.20 |
| 121 | 8.14 | 4.66 | 1.84 |
| 121 | 8.14 | 3.79 | 1.67 |

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The airblast overpressure and dynamic pressure parameters were successfully documented over the two established blast lines and in the vicinity of target response projects. A nonsymmetrical blast was produced by the detonation. Shock-wave perturbations occurring in the recorded pressure-time histories are attributed to various types of anomalies. There were fireball anomalies; luminous jets, nonluminous jets and disturbances created by known and unknown causes. Wave shapes were nonclassical over a pressure range between 90 and 20 psi on line 1 (220° azimuth) and 55 to 15 psi on line 2 (98° azimuth). The electronic and self-recording instrument systems performed well, and the record quality and fidelity were excellent.

Airblast measured at elevations up to 25 feet at 540 and 840 feet was comparable to that measured at the ground surface. Dynamic pressure and dynamic pressure impulse were comparable with past empirical data.

Because of the nonsymmetry of the pressure versus time history of the blast wave recorded at similar radial distances and the repeat occurrence of fireball and blast anomalies from this type of TNT charge, there are several recommendations offered.

1. Free-field blast data should be recorded as close to each target as possible.
2. Wherever practical, station locations along a blast line should be configured so as to minimize the effect of jetting action along a specific azimuth.
3. Target response experiments interested solely in loading from the airblast should seriously consider an explosive source, which is known to be free of anomalies or one which produces a minimum of anomalies.

REFERENCES

1. Giglio-Tos, L., and Pettit, B. A. "Fundamental Blast Studies," PRAIRIE FLAT Event Project LN-101. U.S. Army Aberdeen Research and Development Center, Ballistic Research Laboratories, Published by Headquarters Defense Atomic Support Agency, Washington, D.C. 20305, 1 March 1971.
2. Reisler, R.E. et al. "Air Blast Measurements from the Detonation of Large Spherical TNT Charges Resting on the Surface (Operation DISTANT PLAIN Events 6A and 6)," BRL Memorandum Report No. 1955, U.S. Army Aberdeen Research and Development Center, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland 21005, January 1969.
3. LeFevre, D.P. "Evaluation of New Self-Recording Air Blast Instrumentation," Project 1.36 OPERATION SNOWBALL, BRL Memorandum Report No. 1815, U.S. Army Materiel Command, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland 21005, January 1967.
4. Wells, H.S. "Development and Test of Prototype Miniature, Rugged, Self-Recording Air Blast Instrumentation," Report No. E.I.R. 700 AD 809293, Bendix Environmental Science Division, 1400 Taylor Avenue, Baltimore, Maryland 21204, November 1966.
5. Patterson, A.M. Project LN-102, Blast Anomalies Studies Event DIAL PACK Preliminary Report, Volume 1, Part 1, May 1971, DASA Information & Analysis Center.

APPENDIX--RECORDS OF PRESSURE VERSUS TIME

CAPTION NOTATIONS

The caption associated with each pressure record contains the event number, ground range, and the station number. The first digit indicates the blast line. Successing digits indicate station number, system and channel number, or self-recording system number.

Dynamic pressure data is further identified by the nomenclature listed below.

P_t - Total head pressure

P_s - Side-on overpressure

P_{dc} - Corrected dynamic pressure

Mach - Mach number

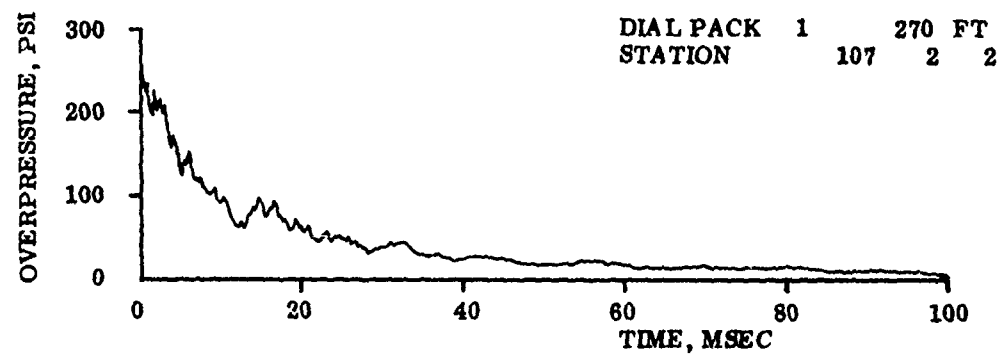
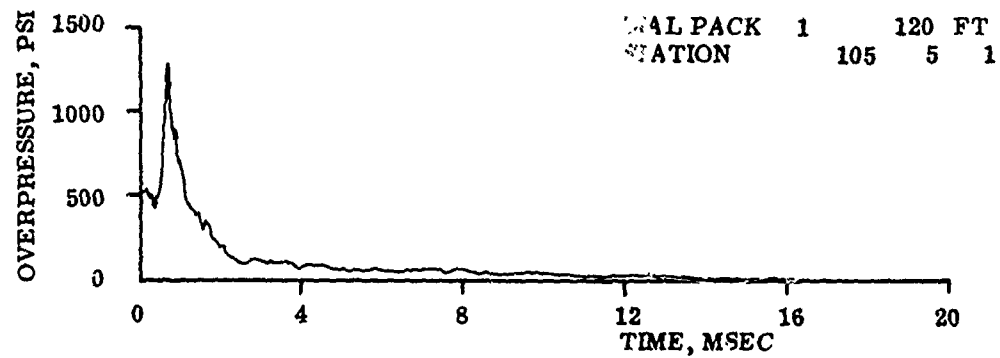
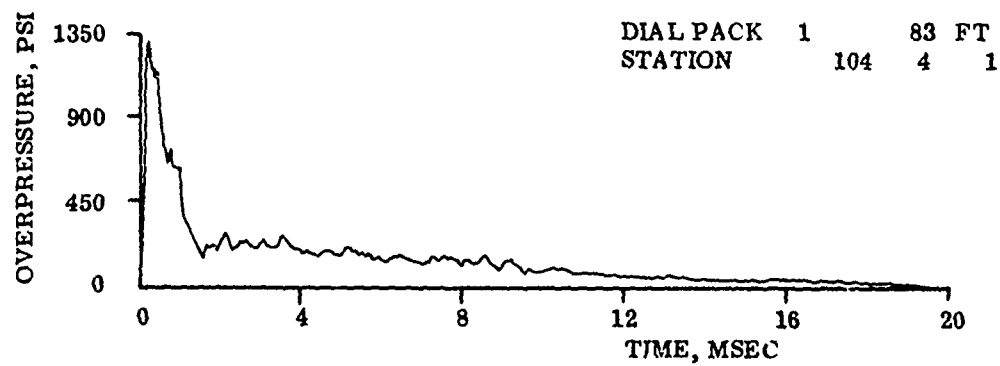


Figure A. 1. --Overpressure versus time, line 1, Stations 104, 105, and 107.

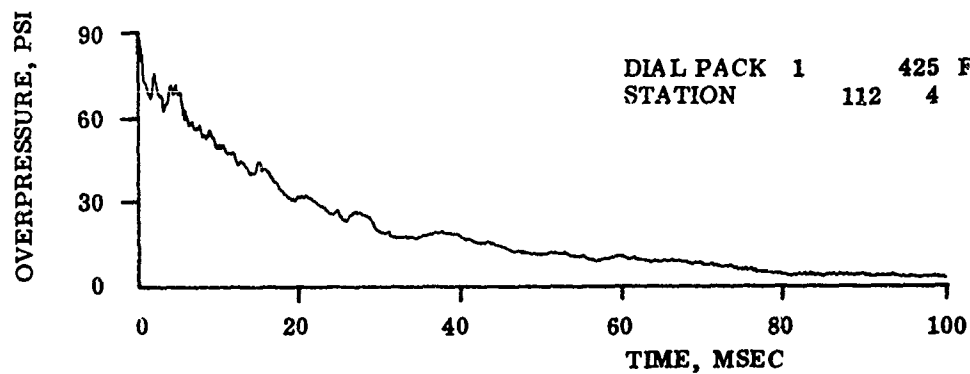
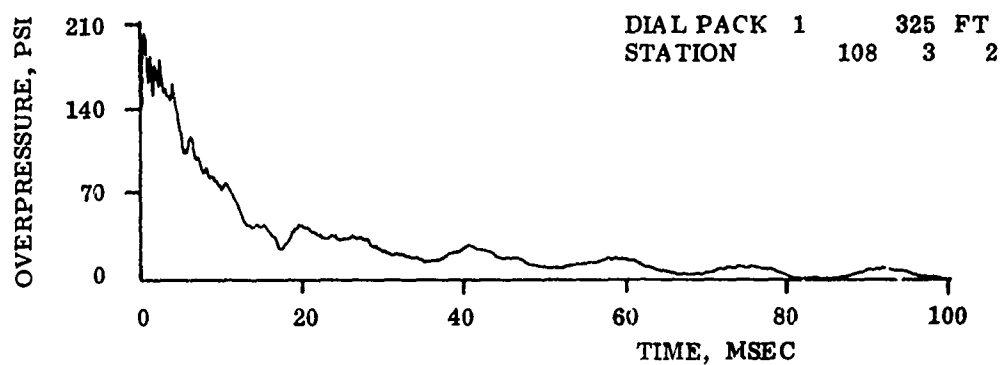


Figure A.2--Overpressure versus time, line 1, Stations 108 and 112.

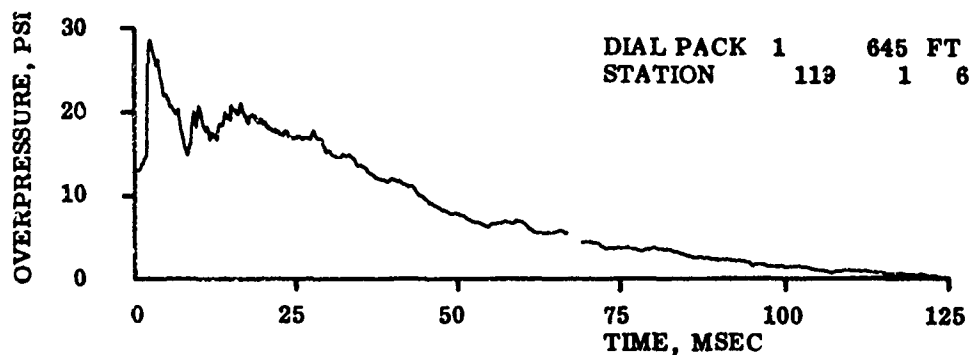
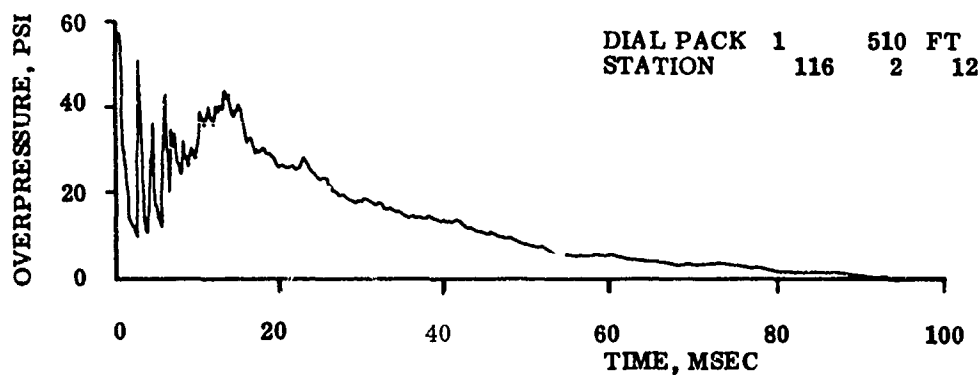
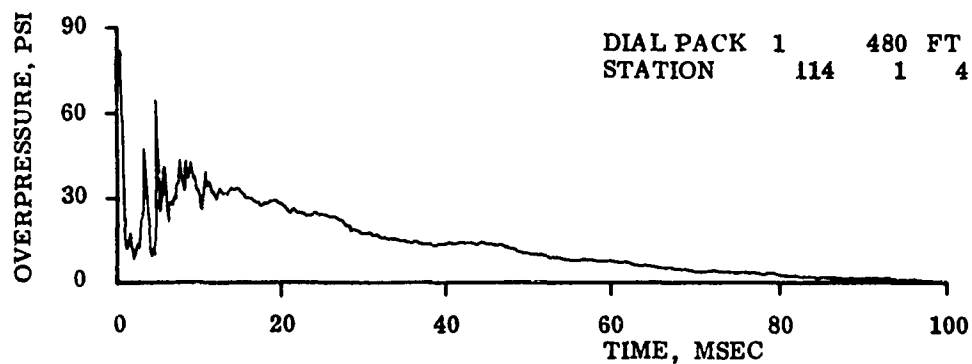


Figure A. 3. --Overpressure versus time, line 1, Stations 114, 116, and 119.

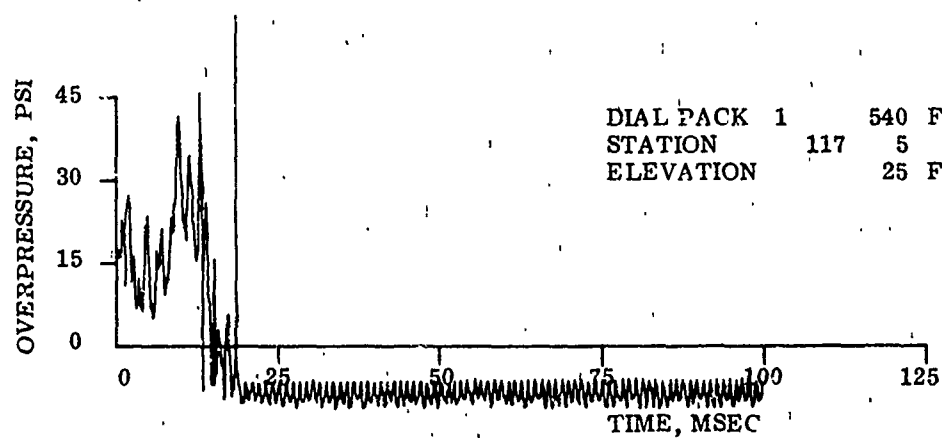
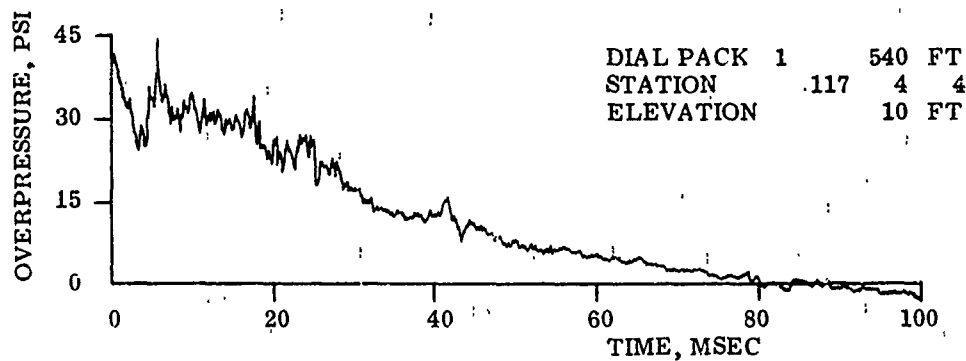
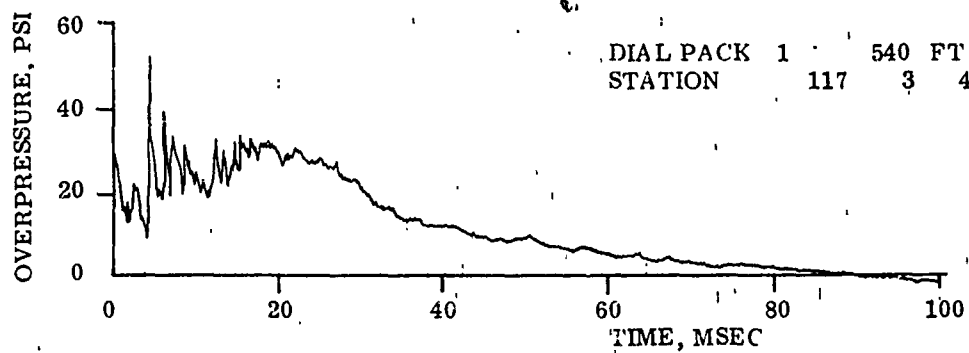


Figure A. 4. --Overpressure versus time, line 1, Station 117.

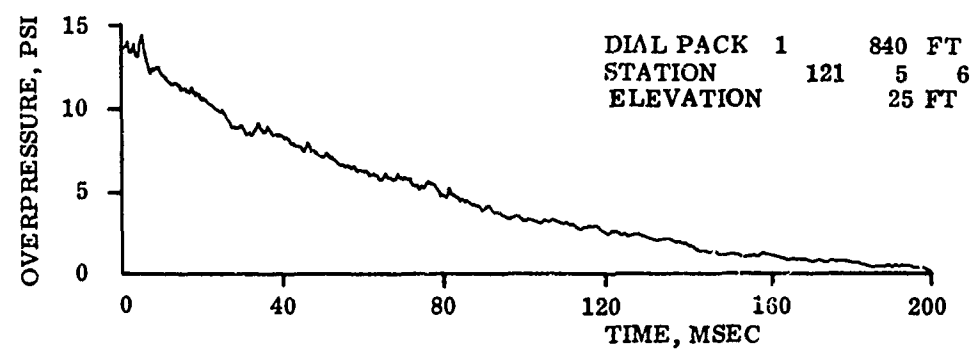
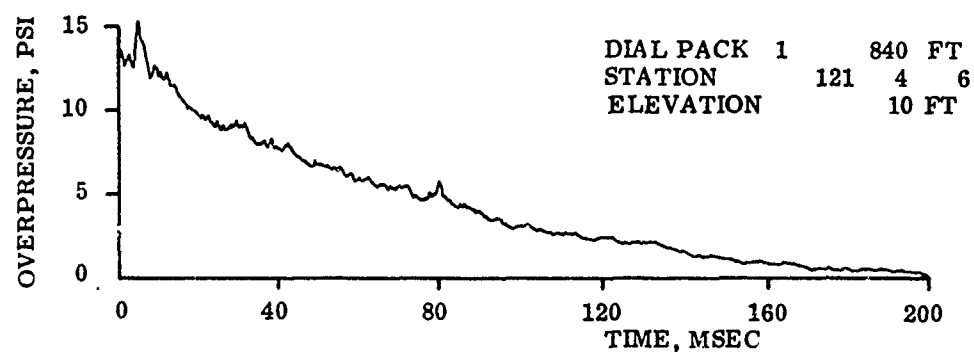
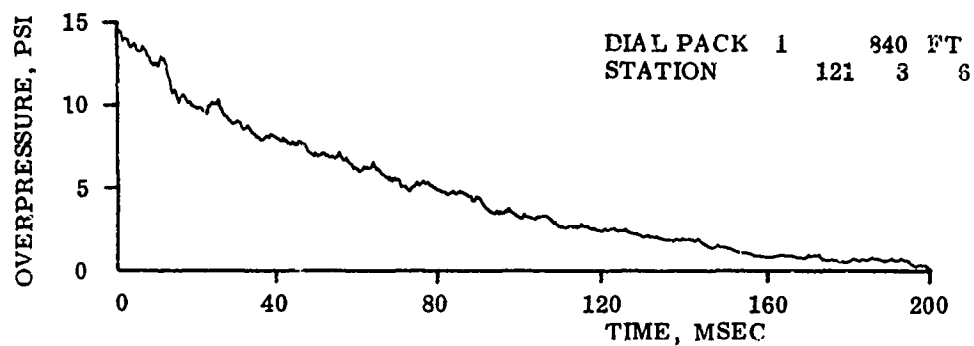


Figure A. 5. --Overpressure versus time, line 1, Station 121.

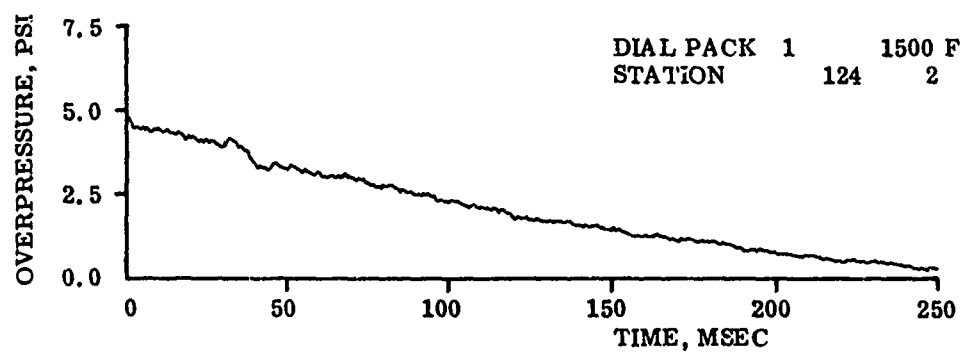
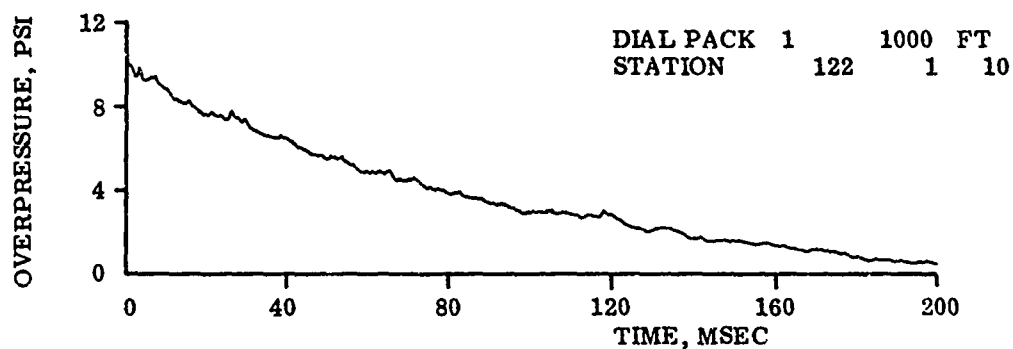
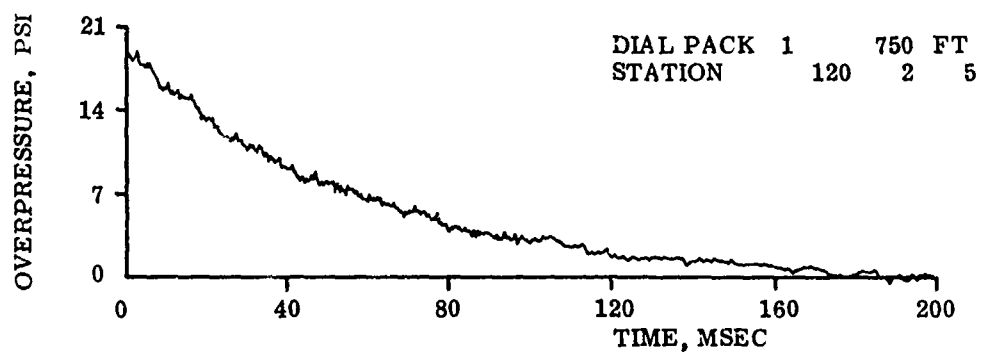


Figure A.6. --Overpressure versus time, line 1, Stations 120, 122, and 124.

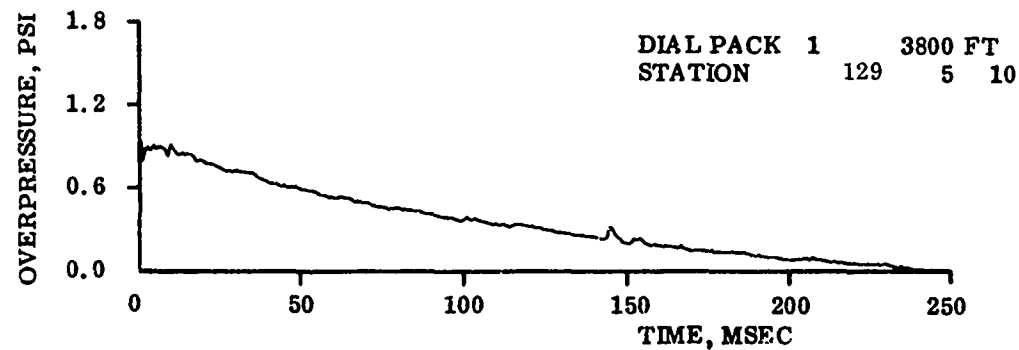
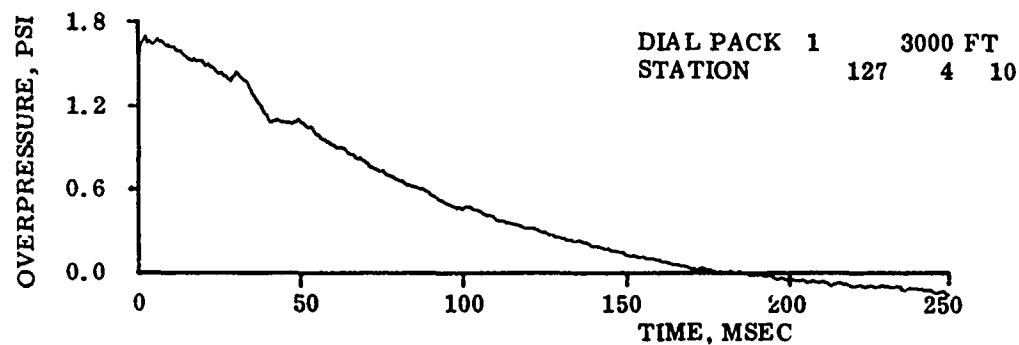
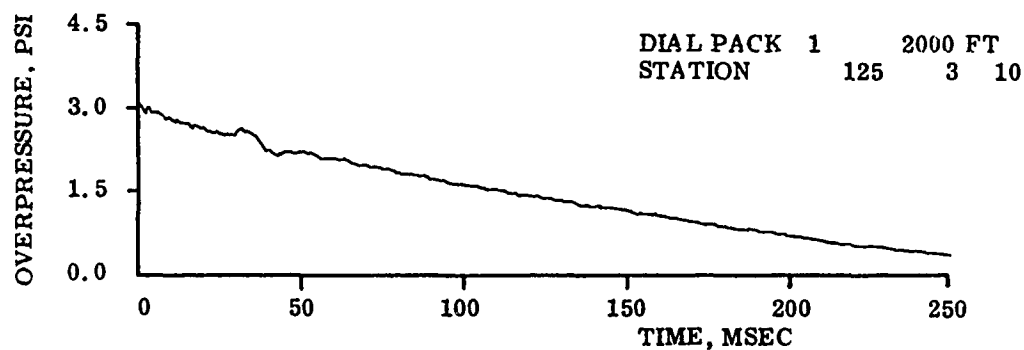


Figure A.7. --Overpressure versus time, line 1, Stations 125, 127, and 129.

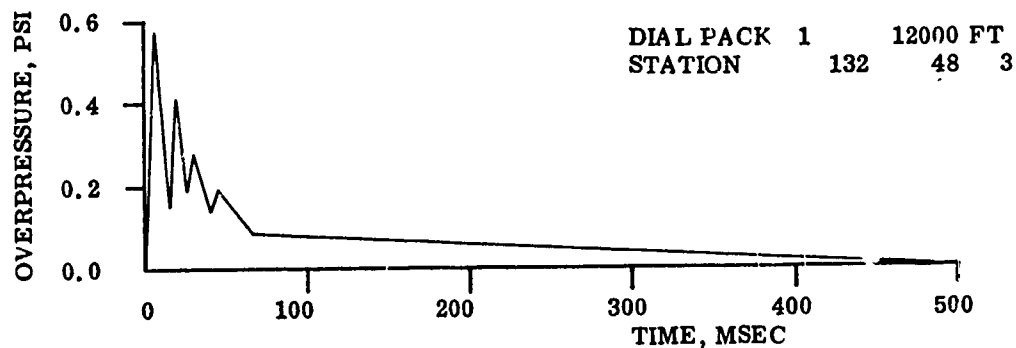
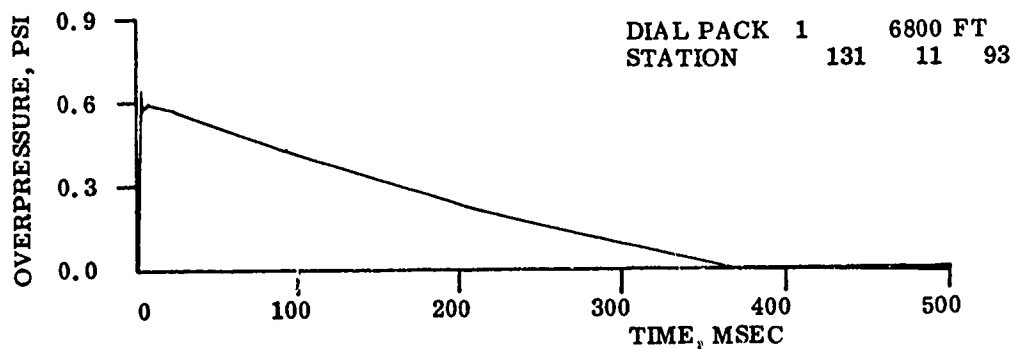
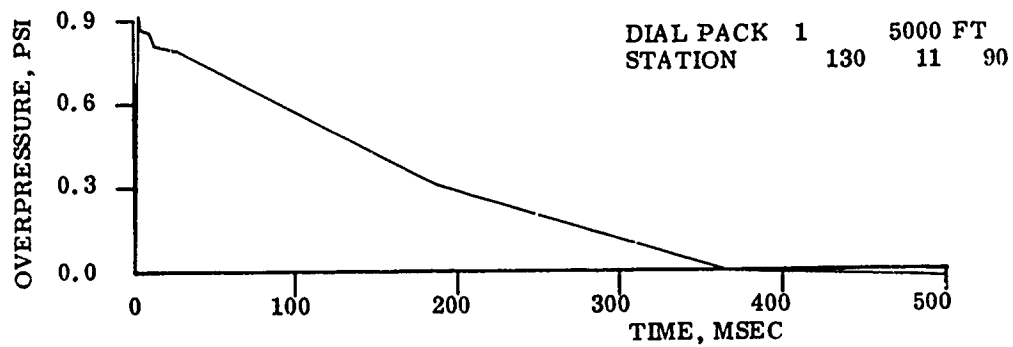


Figure A. 8. --Overpressure versus time, line 1, Stations 130, 131, and 132.

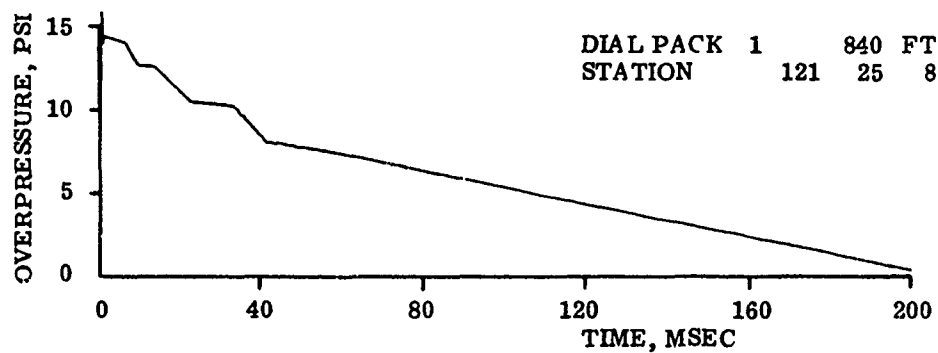
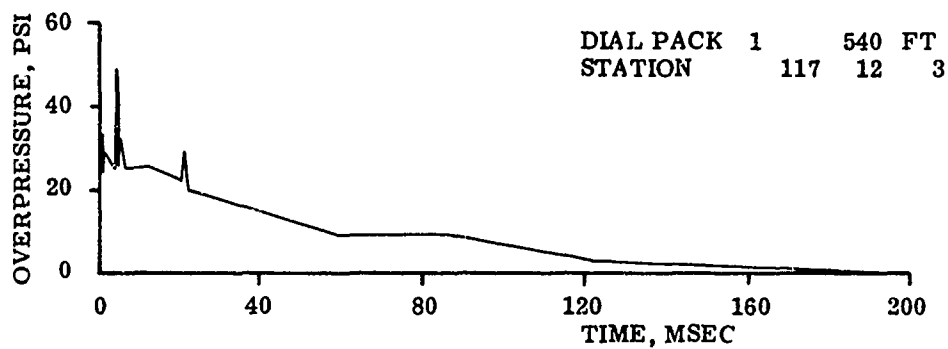


Figure A.9. --Overpressure versus time, self-recording free-field support, Stations 117 and 121.

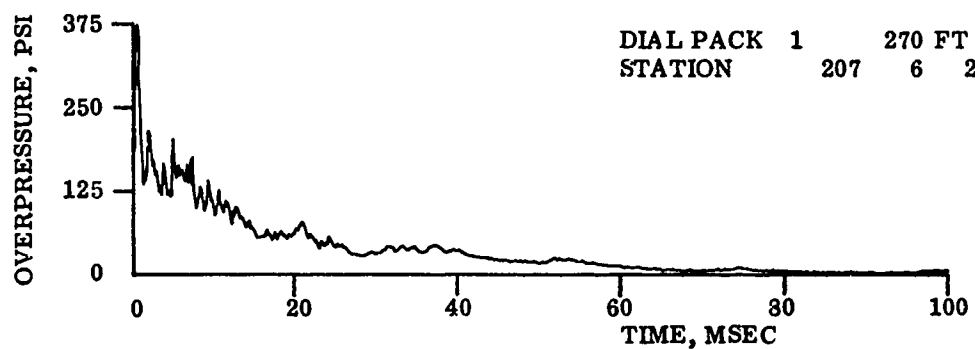
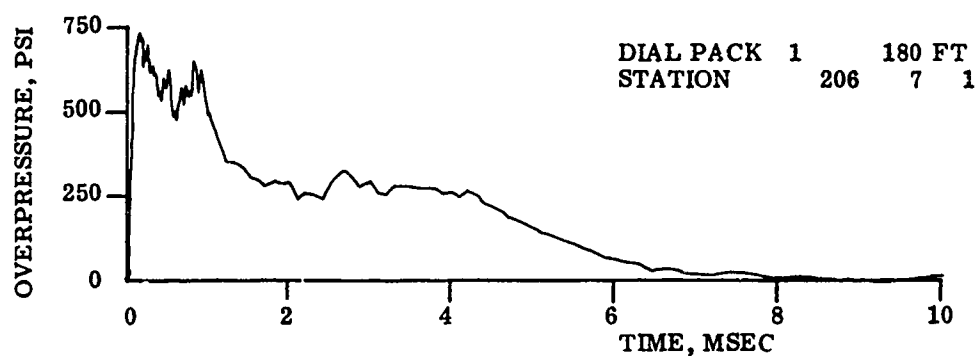
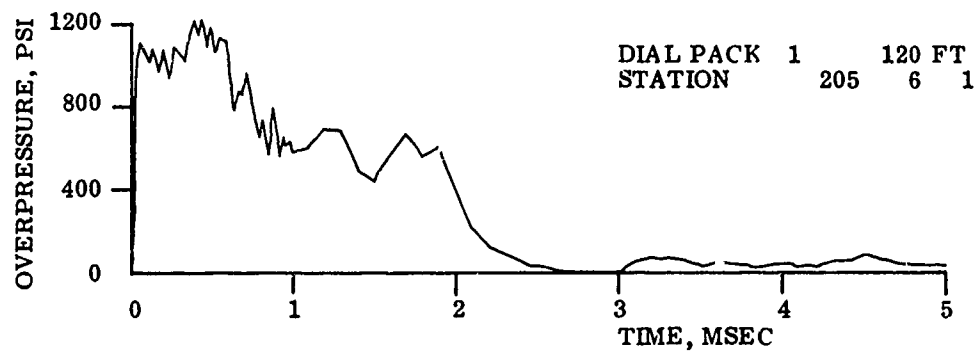


Figure A. 10. --Overpressure versus time, line 2, Stations 205-207.

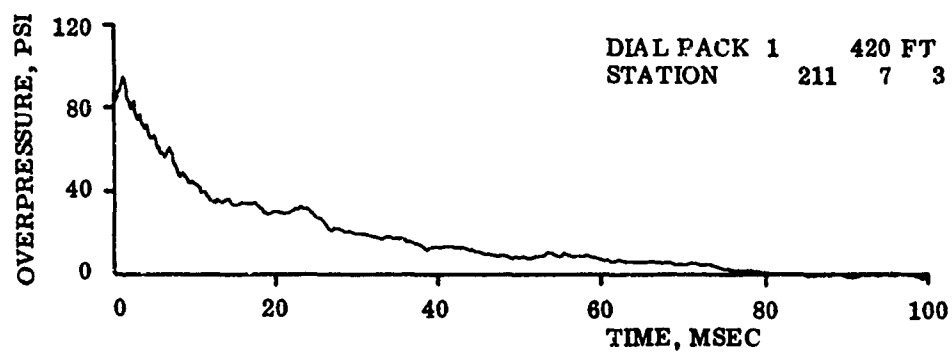
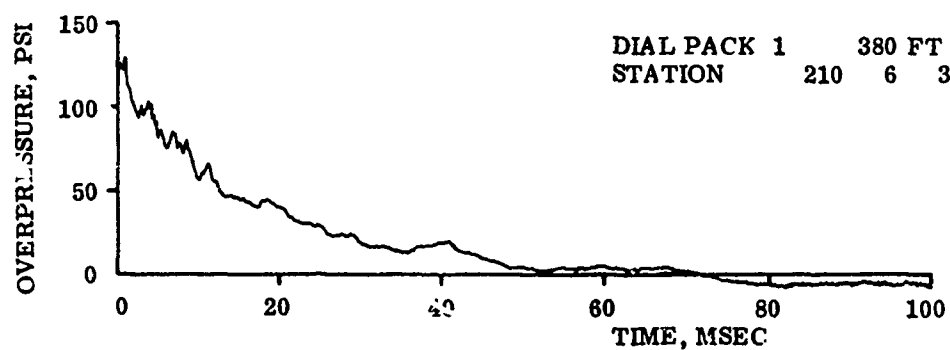
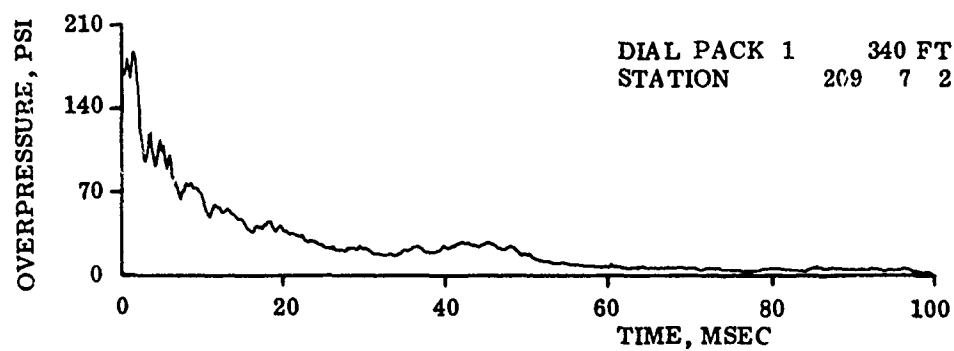


Figure A. 11. --Overpressure versus time, line 2, Stations 209-211.

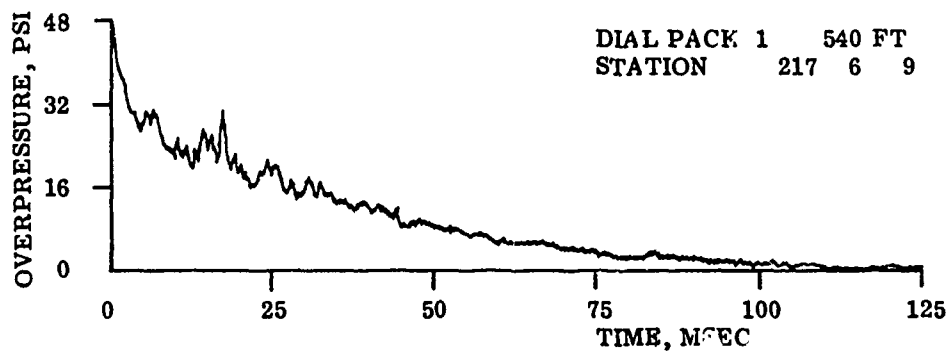
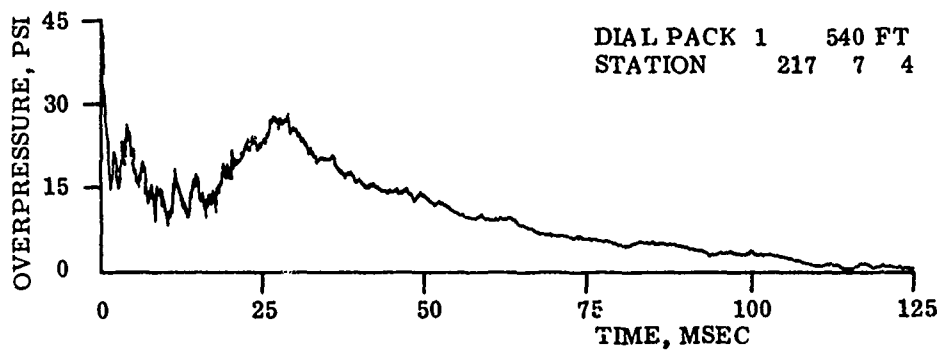
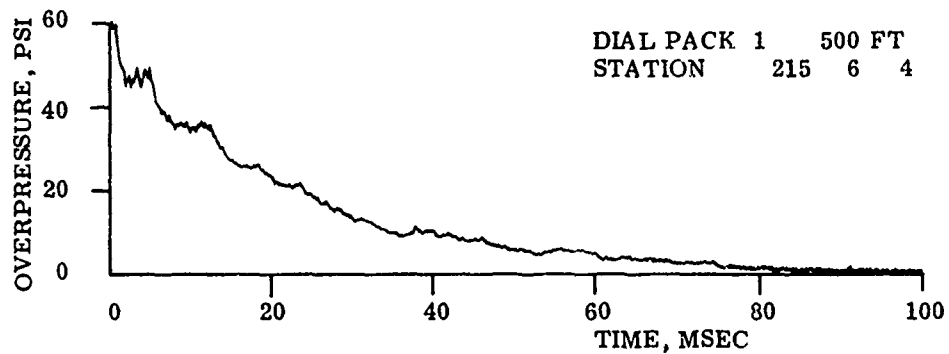


Figure A. 12. --Overpressure versus time, line 2, Stations 215 and 217.

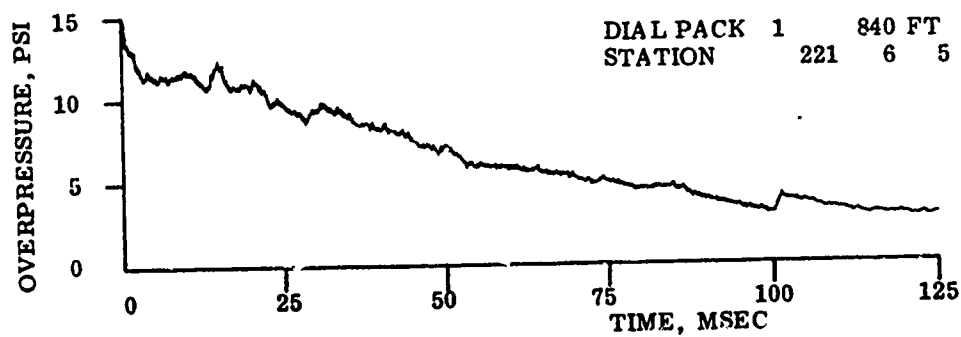
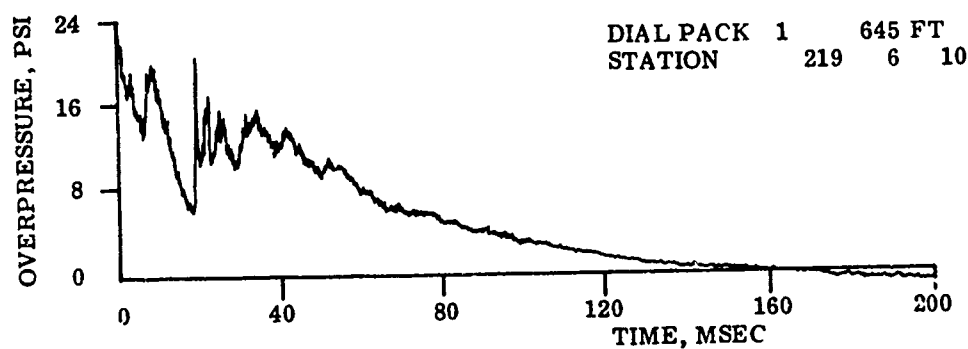
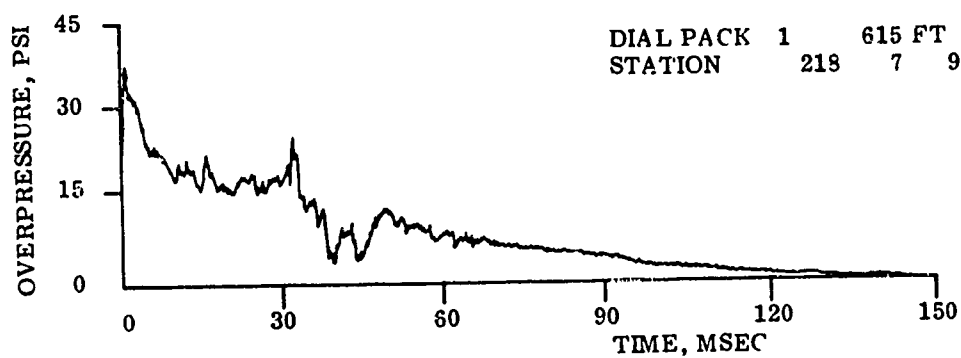


Figure A. 13. --Overpressure versus time, line 2, Stations 218, 219, and 221.

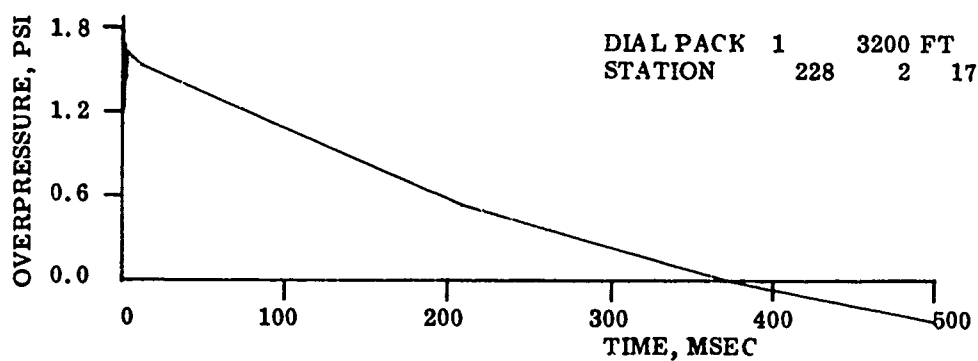
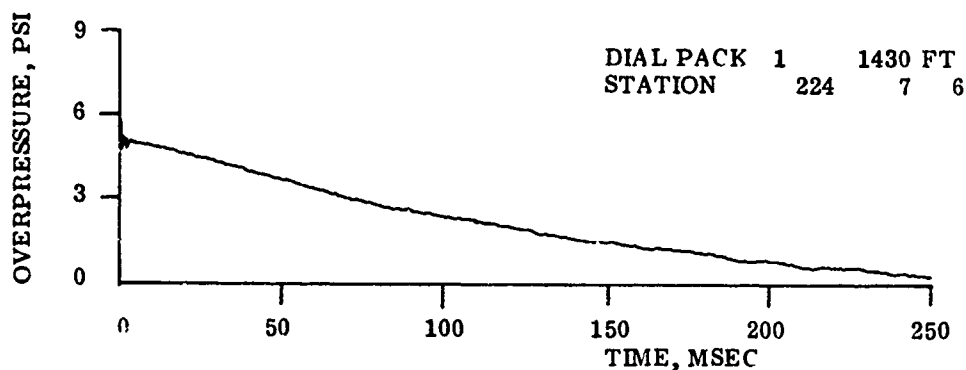
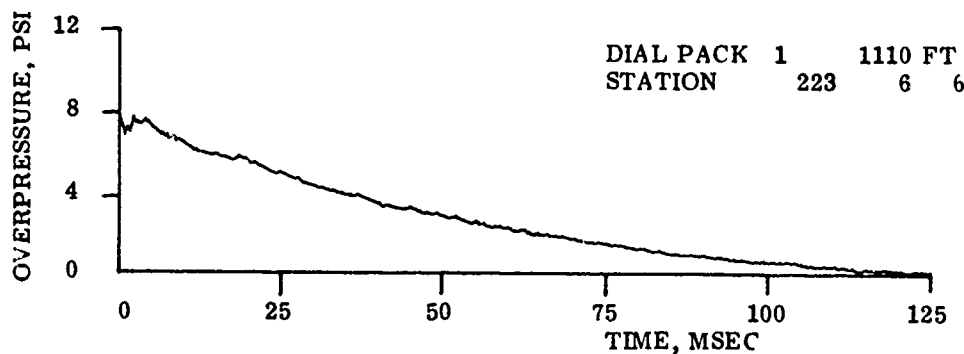
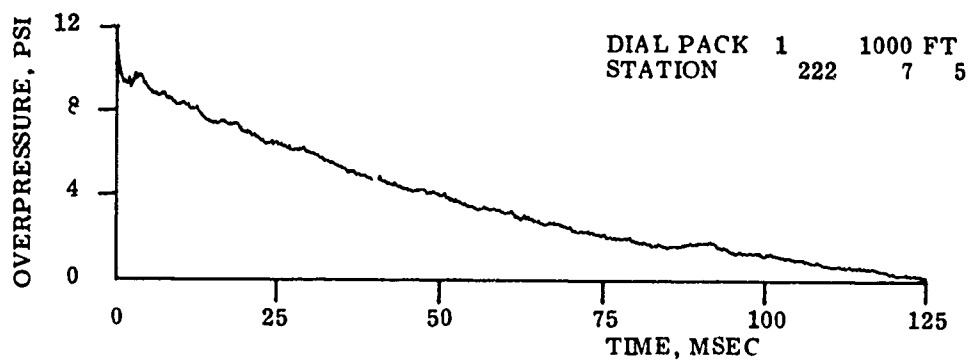


Figure A.14. --Overpressure versus time, line 2, Stations 222-224, and 228.

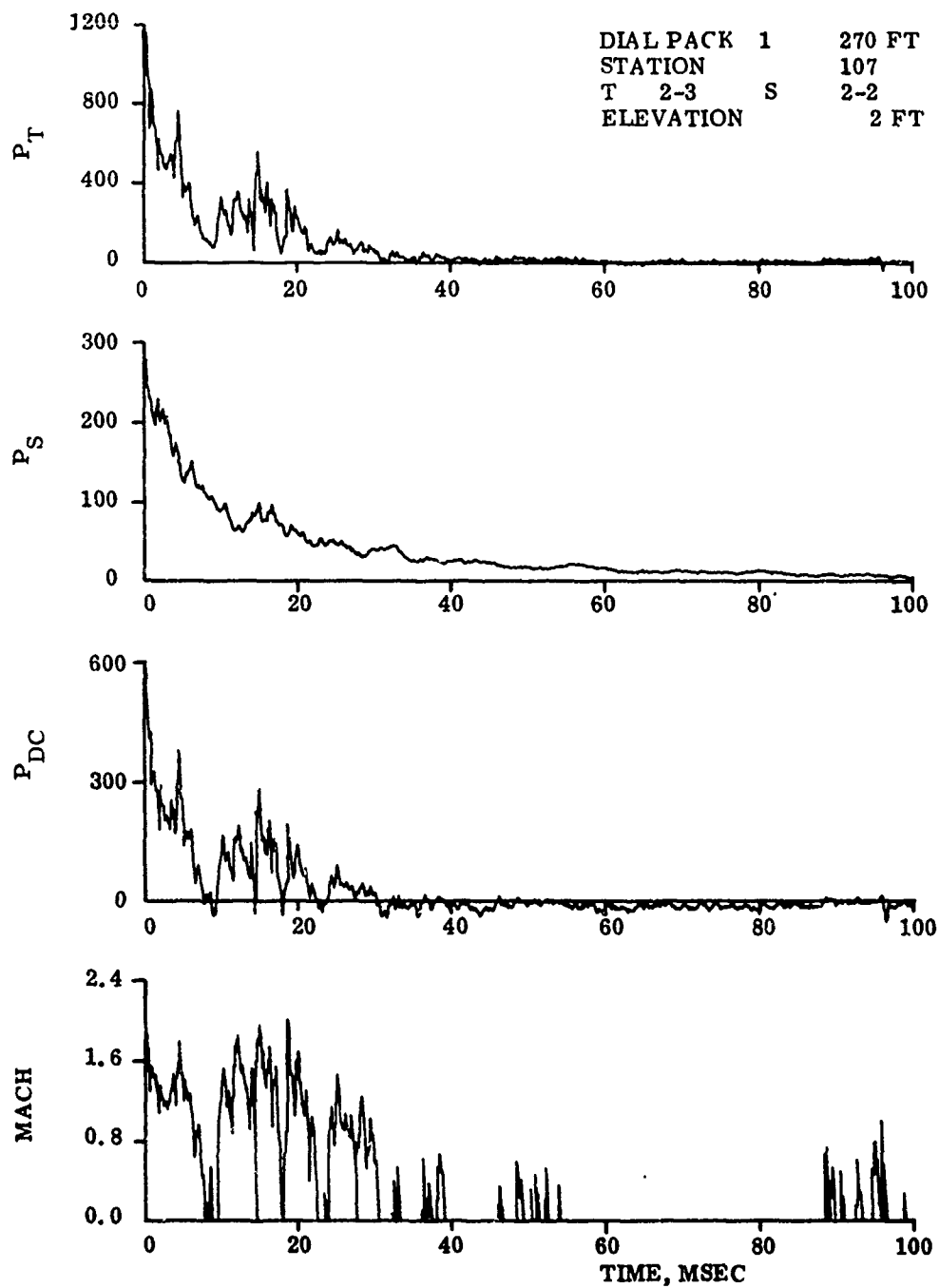


Figure A. 15. --Dynamic pressure versus time, line 1, Station 107.

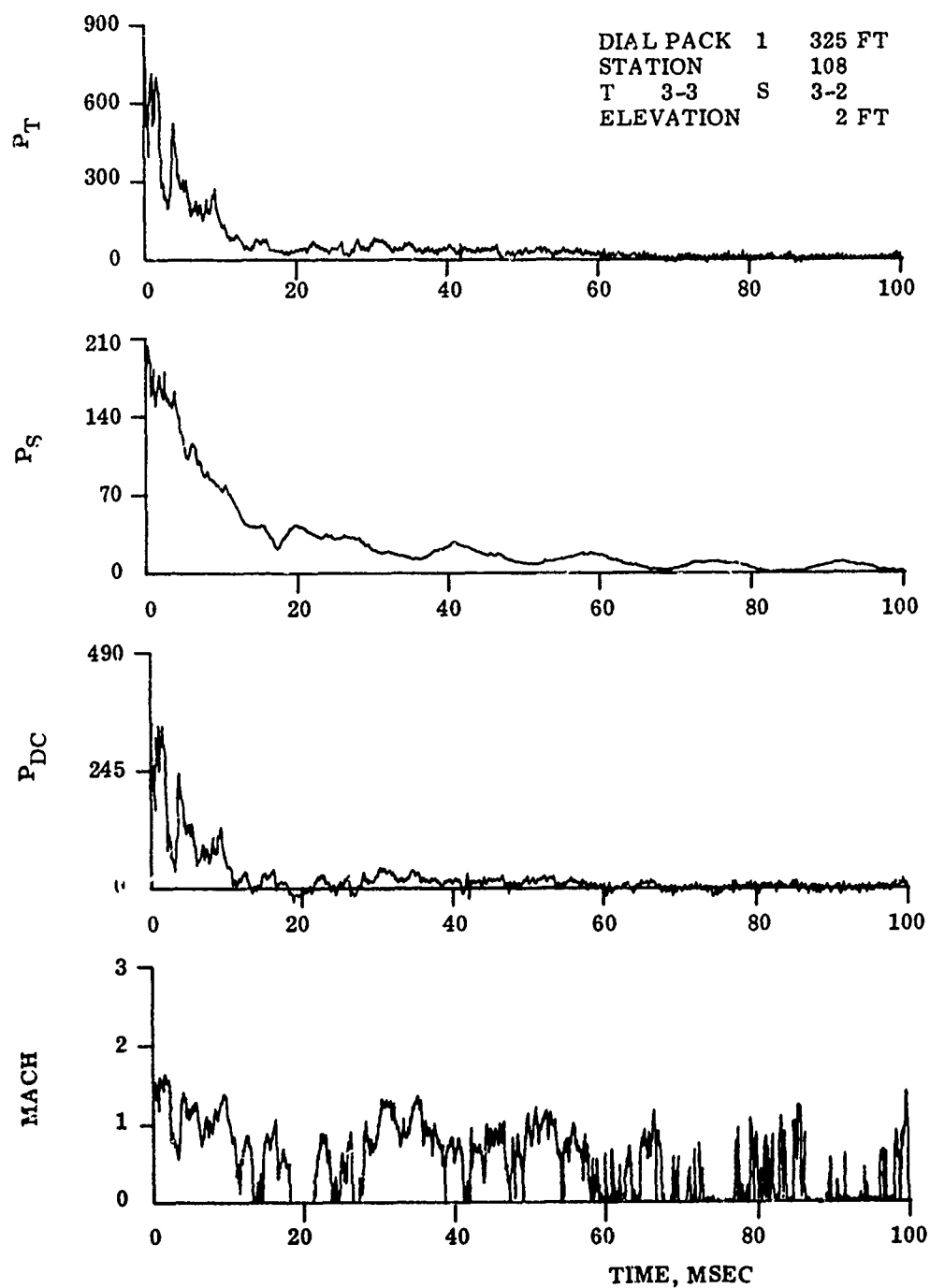


Figure A. 16. --Dynamic pressure versus time, line 1, Station 108.

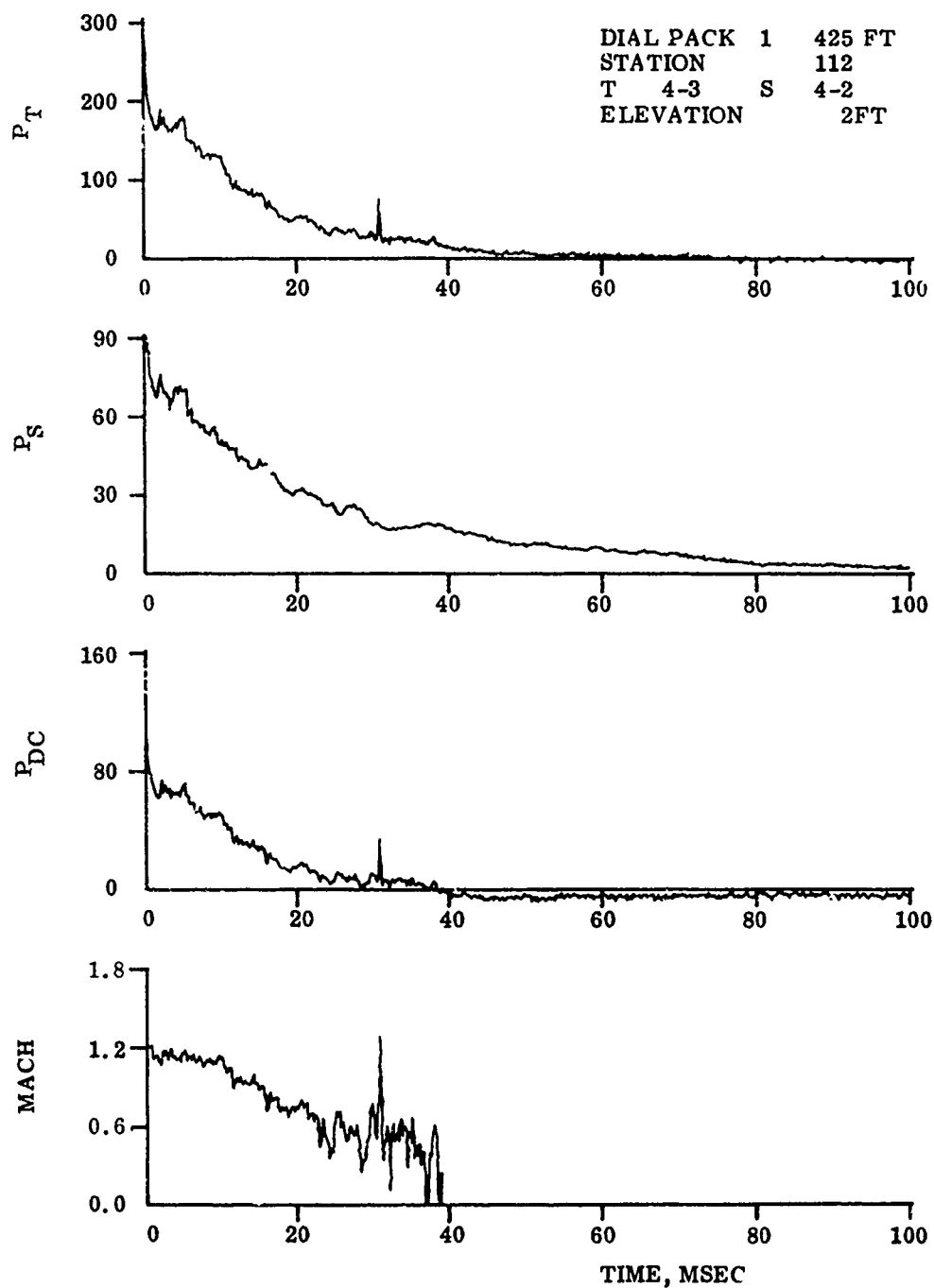


Figure A.17. --Dynamic pressure versus time, line 1, Station 112.

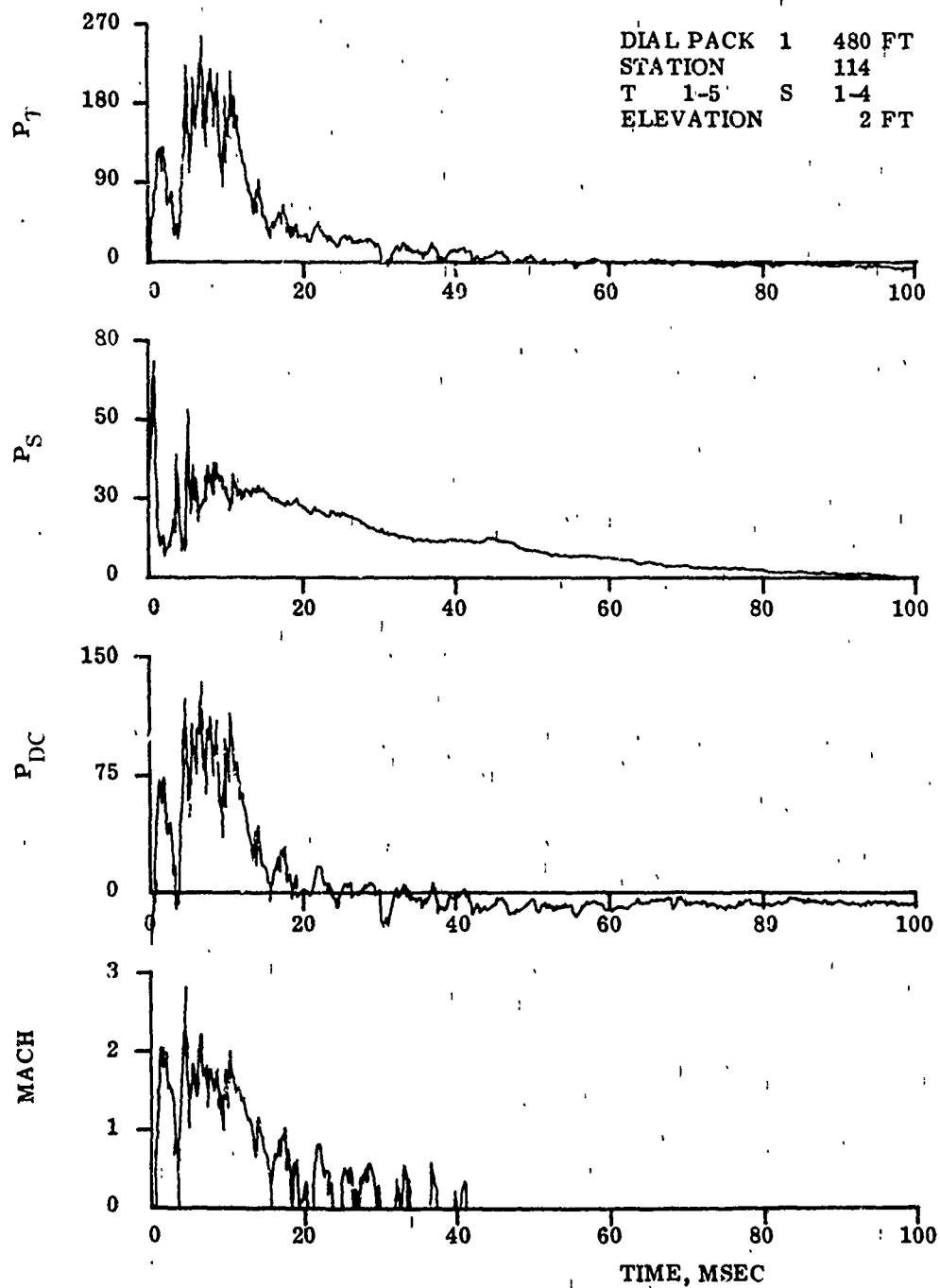


Figure A.18. --Dynamic pressure versus time, line 1, Station 114.

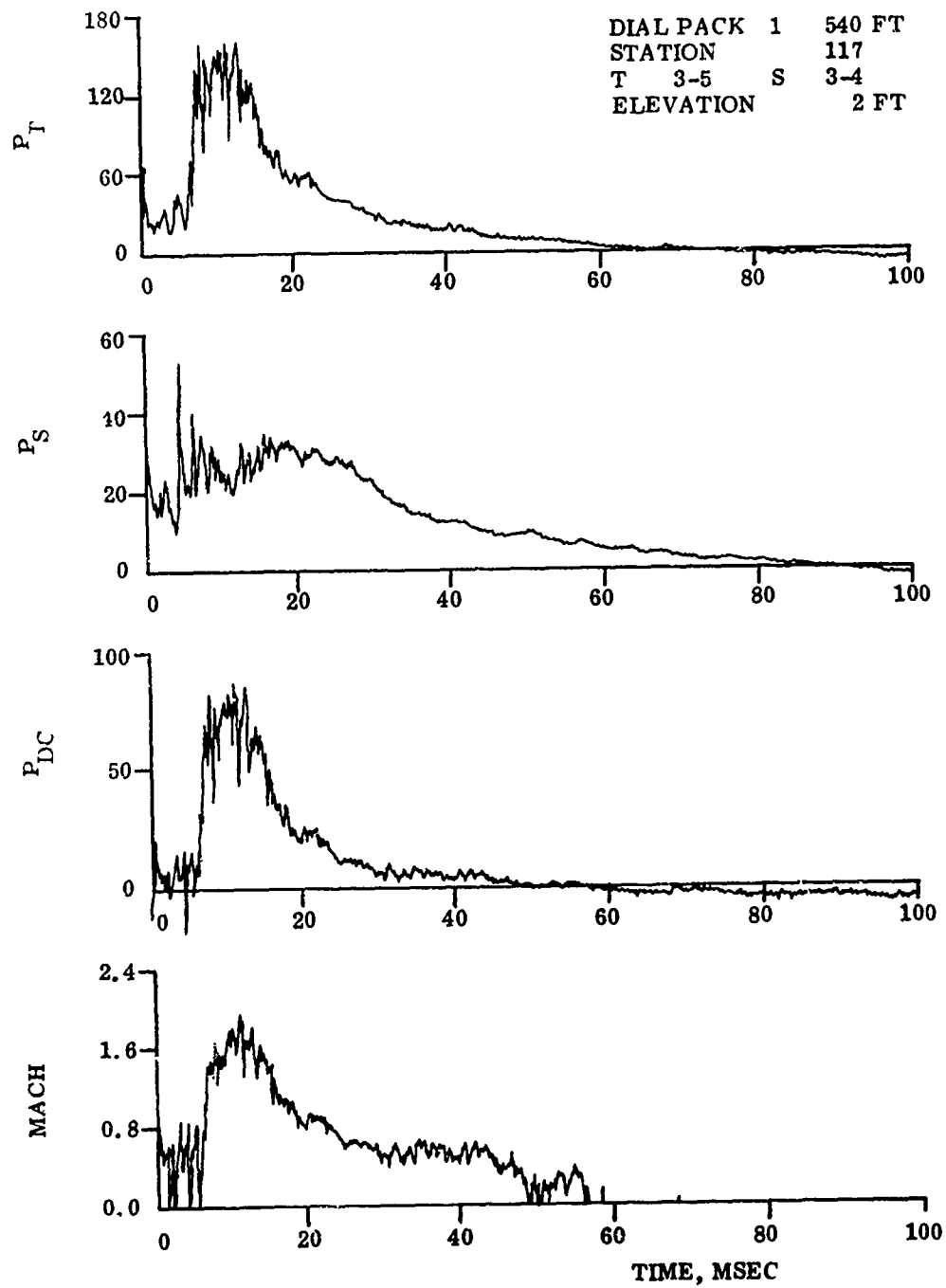


Figure A. 19. --Dynamic pressure versus time, line 1, Station 117.

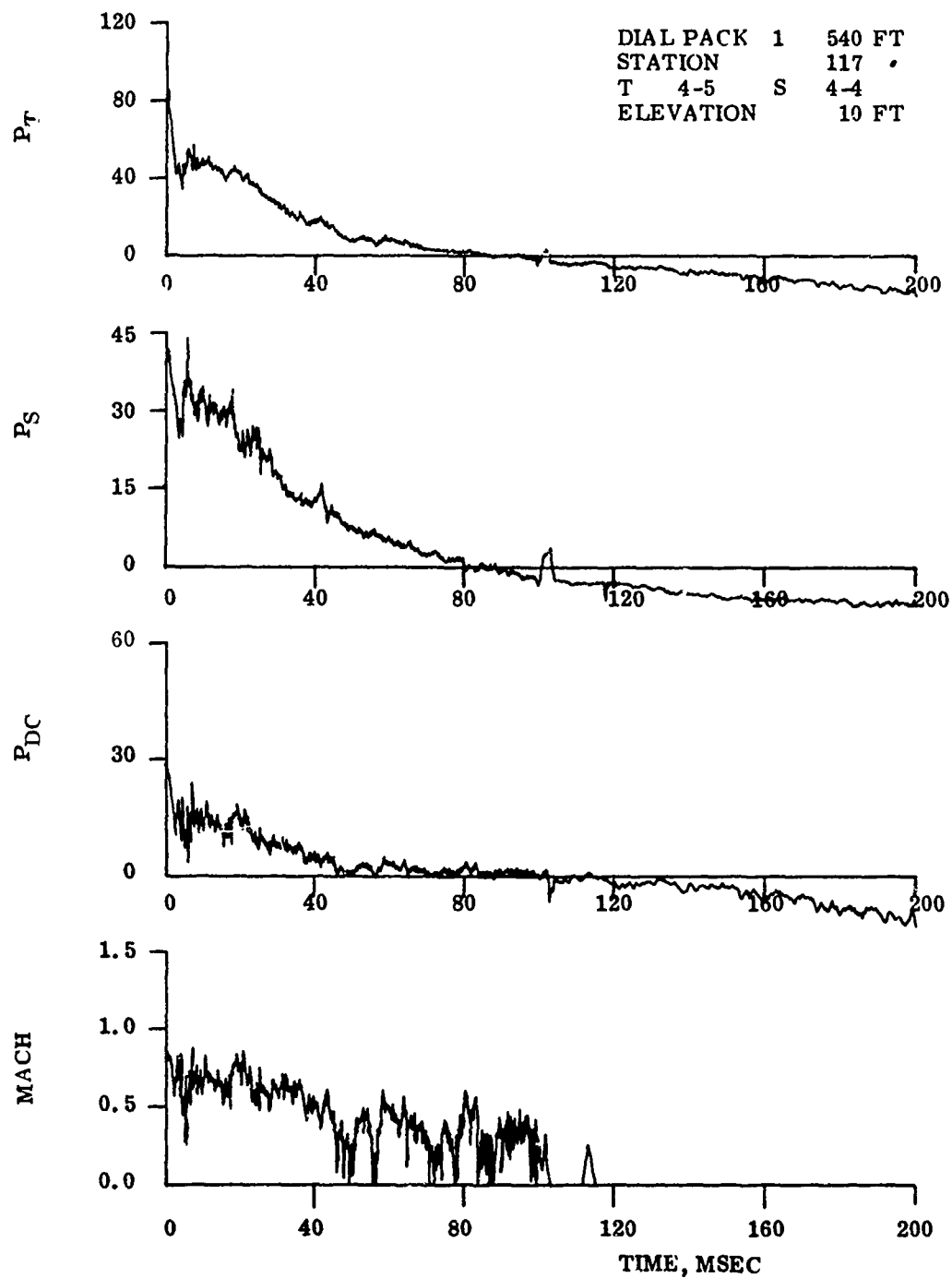


Figure A.20. --Dynamic pressure versus time, line 1, Station 117, 10-foot elevation.

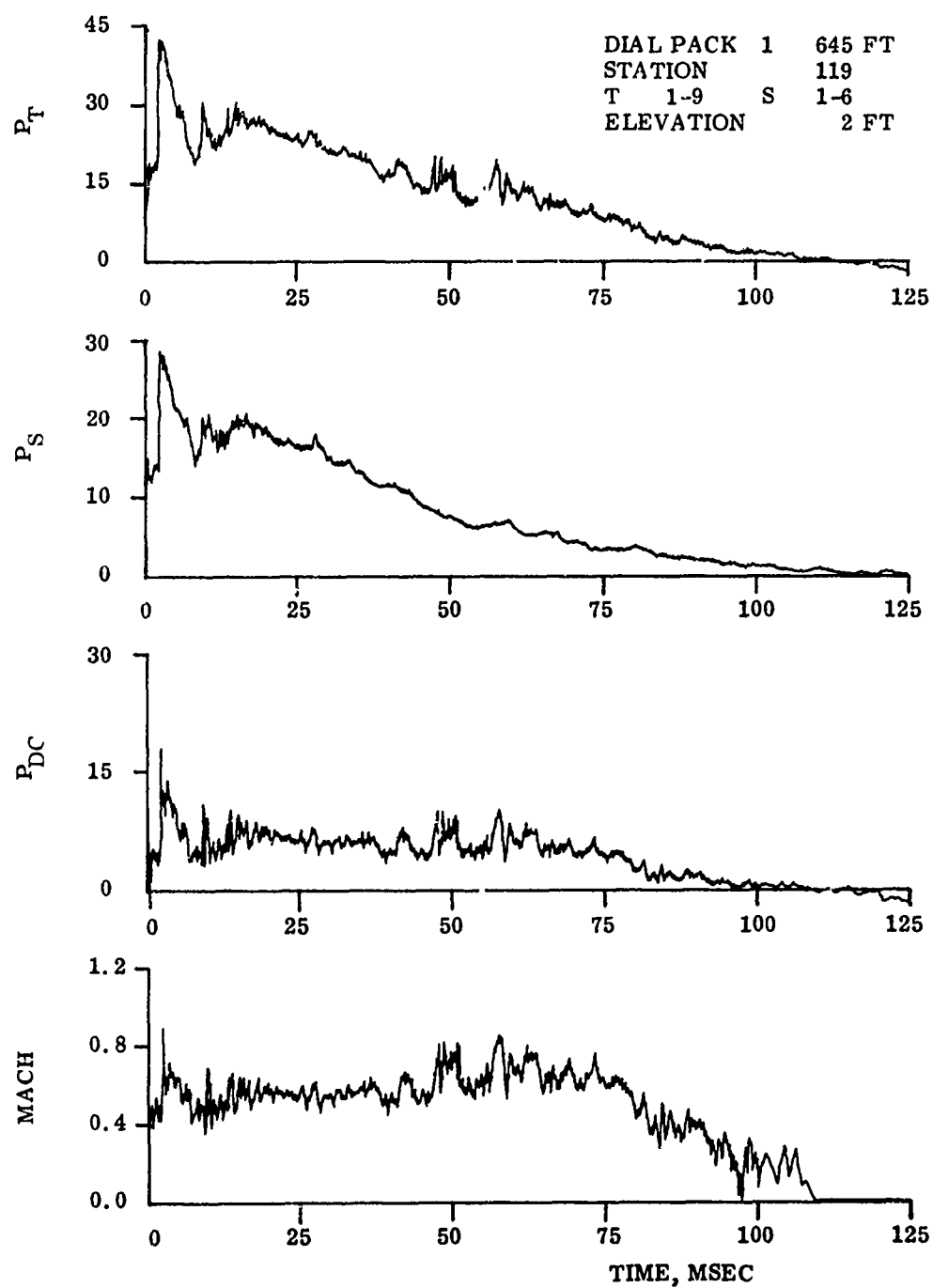


Figure A.21. --Dynamic pressure versus time, line 1, Station 119.

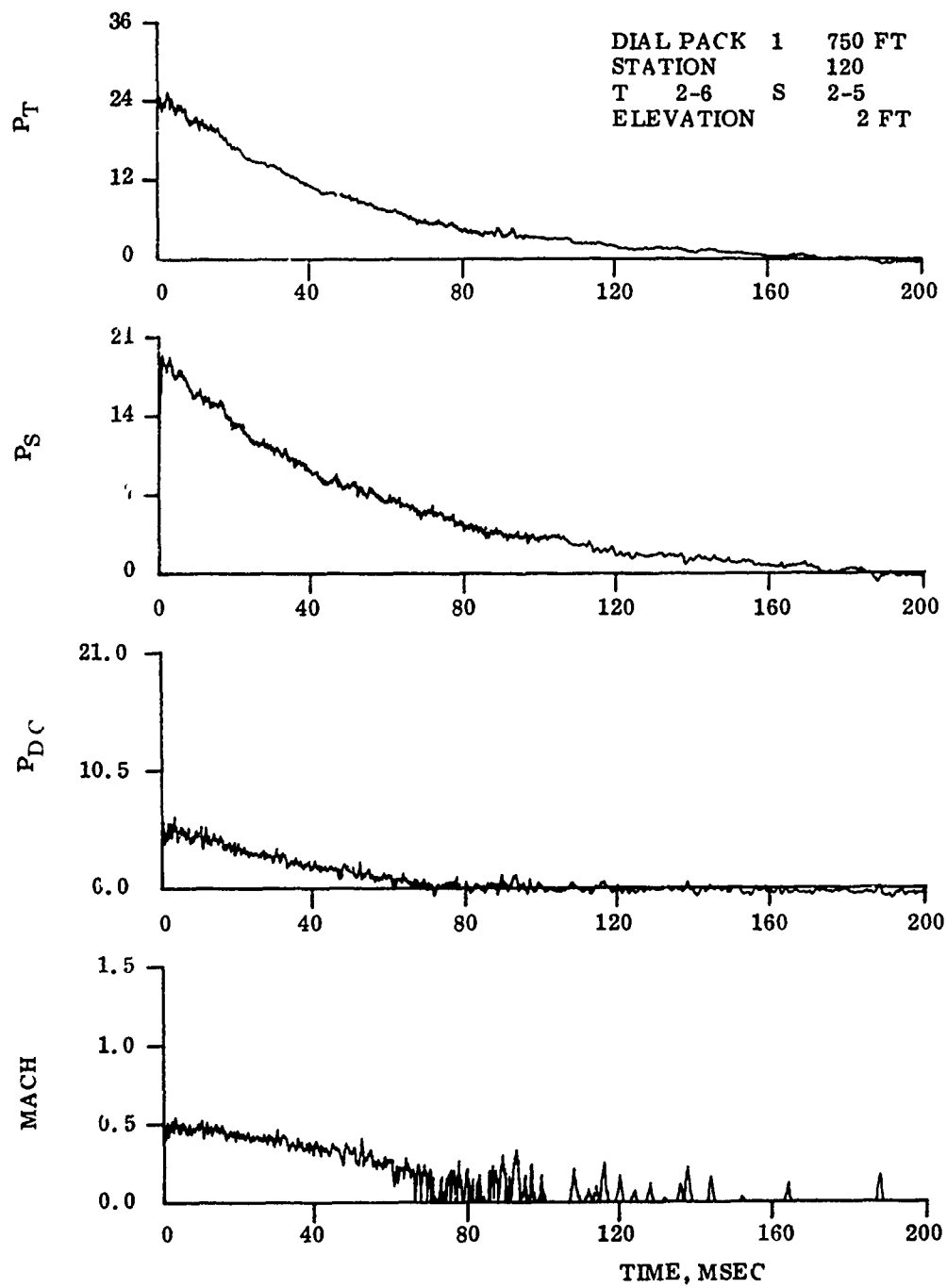


Figure A. 22. --Dynamic pressure versus time, line 1, Station 120.

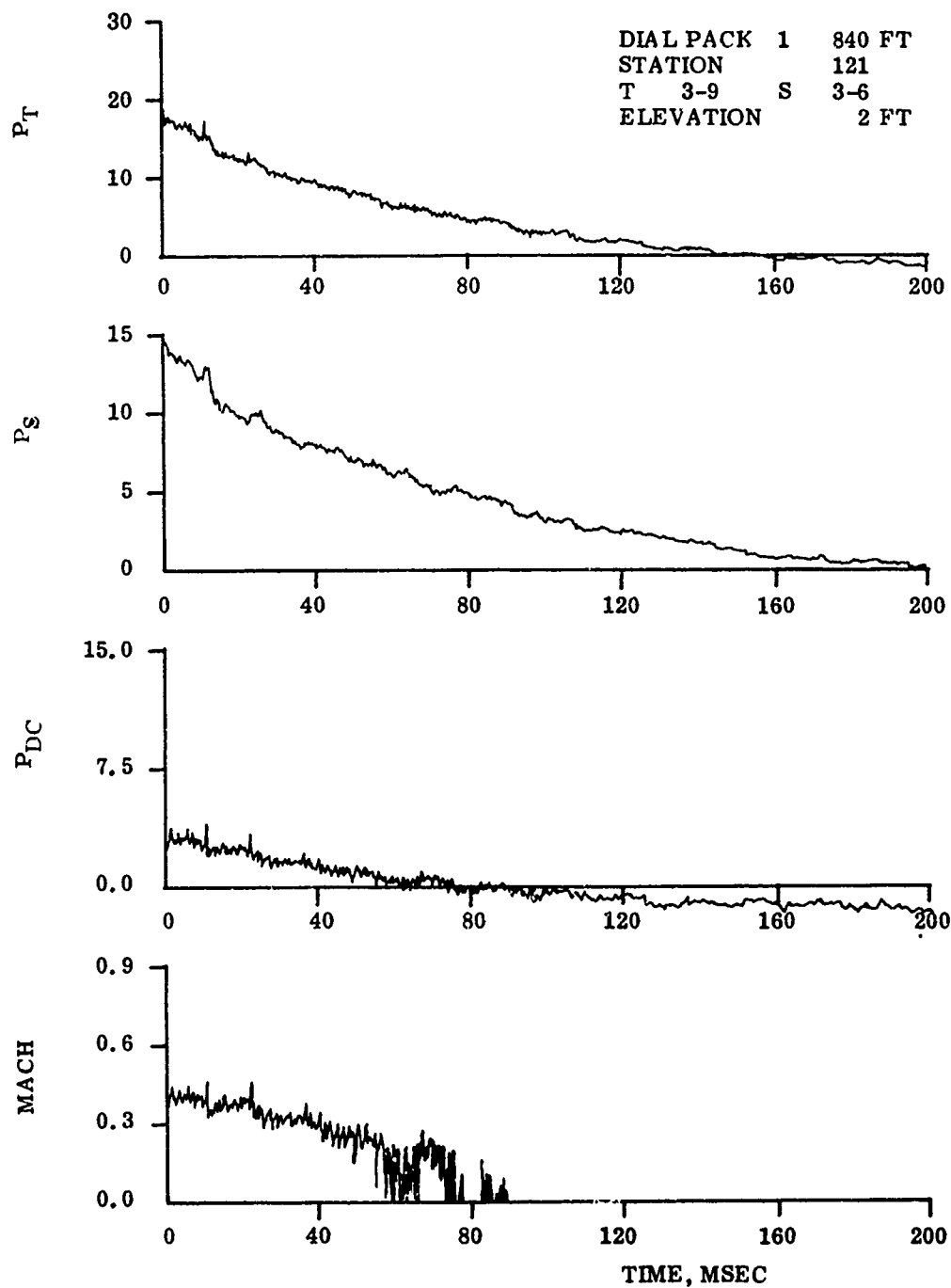


Figure A. 23. --Dynamic pressure versus time, line 1, Station 121.

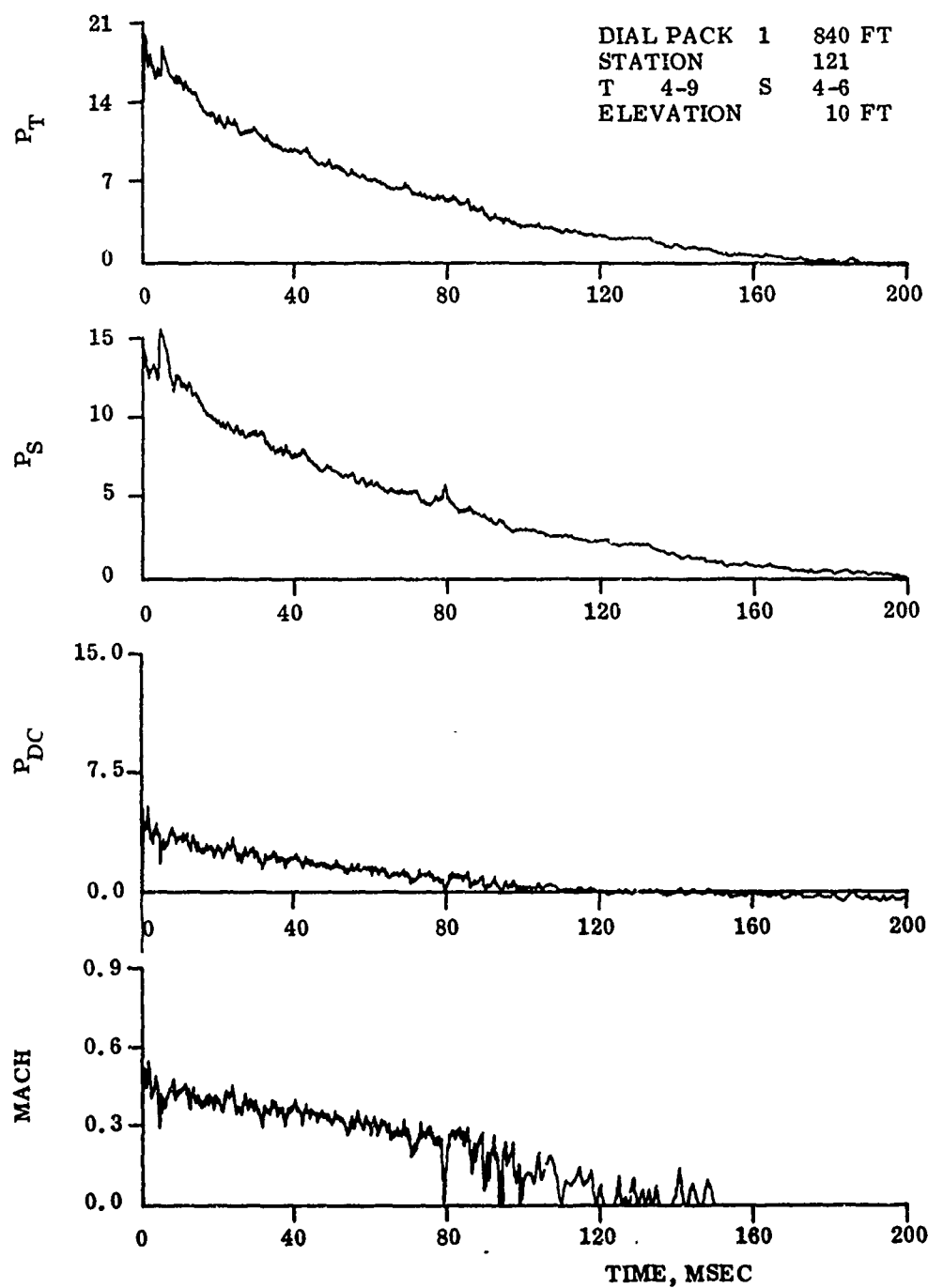


Figure A. 24. --Dynamic pressure versus time, line 1, Station 121, 10-foot elevation.

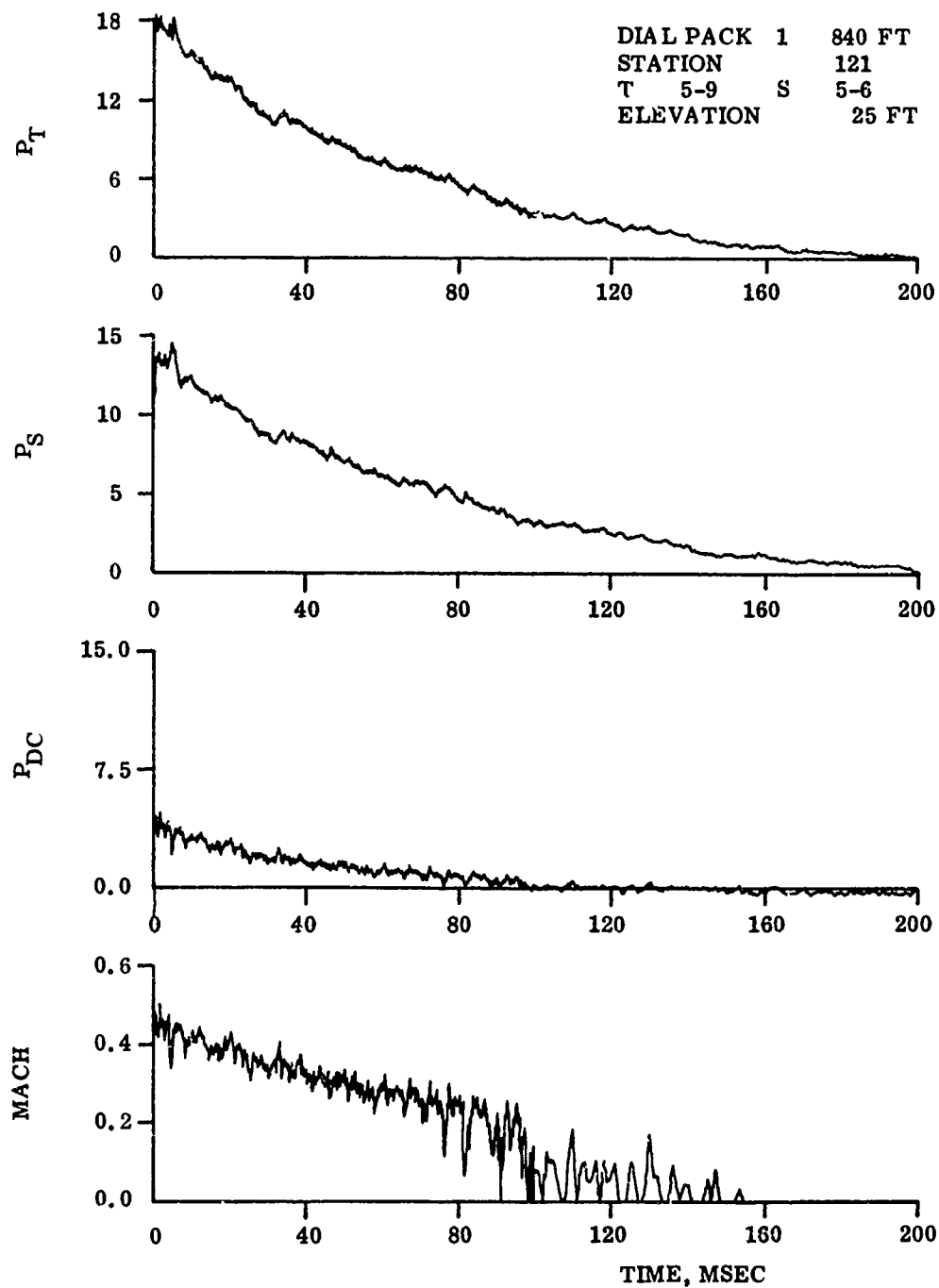


Figure A. 25. --Dynamic pressure versus time, line 1, Station 121, 25-foot elevation.